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29-30 May 1980

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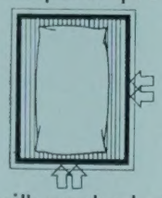

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The new bye-law of the Association came into force from 1st January 1980. The Headquarters of the Association is located in the premises of the CFTRI, Mysore-570 013. At present there are 8 chapters located at New Delhi, Madras, Bombay, Calcutta, Hyderabad, Bangalore, Trivandrum and Ludhiana. The Association publishes a bi-monthly Journal, *The Journal of Food Science and Technology*, which has a wide circulation amongst students, research workers, scientific organisations and food industries.

The Association organises seminars and symposia on topics of importance both at Headquarters and Chapters. Recently, such symposia were organised in the fields of Meat Industry, Cassava, Confectionery, Oils and Fats, Frozen Food Industries, and Pineapple Products Utilisation. The Association has built up good rapport with food industries and with educational and research institutions.

To encourage research and educational activities, the Association has instituted several awards such as Prof. V. Subrahmanyan Industrial Achievement Award, Young Scientist Award, Best Student Award, Gardner's Award and Suman Food Consultants Travel Award.

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FOREWORD

Every industry, big or small, generates products other than the main item of manufacture. Broadly these fall into two categories. One consists of those by-products derived from the raw material or materials being handled, and the other comprises smaller amounts of products that find their way either into the effluents resulting from the industrial operation, or into the atmosphere via the chimney.

In turn, the consequences of these can be compartmentalised. By-products, if simply thrown away or burnt, represent a monetary and natural loss. The aim therefore of any type of processing today is to ensure the maximum economic value for all by-products, if necessary by subsidiary processing. Nothing should in fact be discarded as totally useless. This leads on to the second category of derived products that we are considering, namely the effluents or vapours discharged. The adverse environemntal effects of these in polluting the atmosphere, the good earth, and ground, river and sea waters are increasingly becoming apparent, calling in turn for ways by which to reduce to the minimum the levels of potentially-adverse materials present in all discharges.

The Symposium under way is designed to consider these issues with specific reference to the food and agro-based industries in their Indian context. There may be a tendency to dismiss these issues as less relevant in the area of food technology, since the by-products are usually biodegradable organic materials and the effluents mostly innocuous. A little reflection however will show that there are still areas of concern, which all of us realise when passing by a sugar factory or a starch-processing unit, an abattoir or fish canning unit, a dairy bottling plant or even a fruit-processing outfit. The practice now is to burn any solid product in the boiler, and to run the effluent into streams or municipal sewage systems.

A few examples may be given. The groundnut processing industry gives rise to very large proportions of hulls which are today generally burnt as fuel. Use of this in particle boards has been suggested, but factual data on such utilisation and performance are not easy to come by. Processing groundnut hulls to activated carbons would also be most useful, as would its potential animal feed uses after treatment. The husks from dhal mills, bran and hulls from rice mills, and corn cobs and sheaths from maize processing units also represent utilisable wastes derived from dry milling industry.

Wet milling generates more specialised problems of waste or effluent utilisation. Fermentation of effluents from processing of maize or tapioca and the resulting obnoxious smell are familiar phenomena. There are treatments to minimise this problem and experiences in this regard feature in this Symposium.

Utilisation of slaughter house wastes to produce biochemicals is a well-known field, and several animal, fish and dairy by-products are potentially valuable as feedstuffs.

Equipment has been designed in India to deal with solid wastes, liquid effluents and gaseous discharges, and these will also feature in this Symposium.

The present technical brochure brings together a selection of review articles in various areas to serve as a background for the technical papers that will be presented during the sessions. Eventually the latter, along with the discussions, will be published in the form of the proceedings of this Symposium.

All the Committees that have worked towards the organisation of this Symposium, the personnel of which are listed in subsequent pages, deserve a very special word of thanks. The CSIR has provided facilities to the joint sponsors, namely the CFTRI, Mysore and the AFST (I), and the Department of Science and Technology has contributed to the cost of publication. We are also grateful to the advertisers in this brochure for supporting this symposium on By-products from Food Industries: Utilisation and Disposal.

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By–products Reclamation and Pollution Control in Breweries

N. D. Subba Rao

United Breweries Ltd., 24, Grant Road, Bangalore, Karnataka

Today's byword should be by–products. Anything that ultimately emerges as a waste product, after processing of the final marketable consumer product, is a potential hazard to environmental pollution. The days of somehow diluting the wastes and leading them to the God's own territory of sea, rivers and lakes have boomeranged. Such seemingly easy methods of disposal have threatened the very survival of mankind and Futurologists have predicted a bleak picture, for people who have to inhabit this planet after 2000 A.D., if timely and enduring measures are not implemented here and now. In the above context, the present AFST Symposium is a step in the right direction.

'Economic processing of by–products and waste treatment to avoid environmental pollution by food and allied industries in India' in general is a relevant theme. Here I wish to dwell on certain salient points as applicable to breweries, where beer is produced, and falls into the category of a major fermentation industry.

Beer brewing is sustained by major agricultural product inputs, in the form of barley malt, cereal adjuncts, sugar and hops. Beer is a low alcohol containing beverage, popular the world over, with an estimated production of over 800 million hectolitres. Production figure for India in 1979 was around 1.75 million hectolitres. Basically 75% of the raw materials are extractable as fermentable sugars in a brewery plant. The balance quantity requires economic handling to be converted into useful byproducts.

A bird's eye view of the operations in a Brewery, will suggest that seemingly waste products, can be profitably converted into useful by–products. Indirectly it will mitigate the problems of additional load of the effluent. The principal by–products of beer manufacture are:

1. Brewers' spent grains
2. Hot and cold trub
3. Spent hops
4. Carbon-di-oxide
5. Brewers' yeast

1. Brewers' Spent Grains

After having taken the extract from the malt and adjunct mash, the residual matter is available as' Brewers grain'. It can be in wet condition for quick disposal or will have to be dried in a special grain drier, to enhance its keeping quality, which requires energy inputs in the form of steam and compressed air. Brewers' grain is a universally accepted substitute for animal feeds and feed formulations.

In the opinion of the Author, screw conveyor and small quantity of steam for discharge of grains from the Lauter Tun to the spent grain discharge hopper is the most economical way of handling wet grains in a brewery. Typical analyses of Brewers' Grain is given below.

	Wet grains (approx. %)	Dried grains (approx. %)
Water	76	9
Total proteins	5.5	21
Digestable proteins	3.7	15
Fats	2.3	9
Nitrogen free extract substances	10	40
Fibre	5	18
Mineral matter	1	4

The fats as well as the extractive substances are of immense nutritive value. Their digestive coefficients when used as fodder being 88 and 62 respectively. Protein content, which is considerably higher in dried grains than in cereals, makes it a valuable fodder. According to Nils Hansson, a Swedish authority one fodder unit (approximately equivalent to one kg. barley) is 5 kg. wet or 1.3 kg dried grains. Brewers' grain contain mineral substances like phosphates, and a certain amount of soluble malt sugar extract also, since the process of extraction from the Lauter Tun is stopped at about 1.5° Plato due to other technical reasons in a Brewery.

2. Hot and Cold Trub

These are protein-tannin complexes that sediment out during the boiling and cooling of wort, before the start of fermentation. Again a certain amount of cold trub from Secondary fermentation separates and settles down along with yeast in the lager tanks.

Usually the largest accumulation of hot trub settles in the form of a cone, due to centripetal action in the whirlpool separator. This can conveniently be pumped to mix with the Spent Grains.

Cold trub mixed with yeast, can be dried in drum yeast drier, where it finds use along with the dried yeast.

3. Spent Hops

This is the material available from the Hop Back in a brewery. The quantity in proportion to malt employed is at such a small ratio, it is sometimes mixed with Spent Grains for animal feed purposes in large Breweries. It

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4. Carbon-di-oxide

Depending on the original extract and degree of fermentation, 1.5 to 2 kg. of CO_2 per hectolitre of beer fermented is available, which follows the simple Gay-Lussac law. The gas can be collected, purified, compressed and liquefied for storage under pressure. In a brewery the reclaimed CO_2 is used for beer transfers, counter pressure and carbonation. Any surplus gas can always find its way to the aerated soft drinks manufacturer.

5. Brewers' Yeast

In a brewery, fermentation is triggered off by yeast. Malt wort is an ideal medium for growth and proliferation of yeast. Type of yeast employed, temperature modulation and pressure are ideally controlled to produce beer of set characteristics. Generally yeast crop in brewery fermentations is four to five fold, yield being 15 kg. per 100 HL beer. Although some amount of Yeast is reused for pitching in subsequent fermentations, the surplus yeast is sent to a drum drier, to be available in dry flakes or powder form. Brewers' yeast finds use as a nutrient medium in special fermentations for production of antibiotics. It is rich in vitamins of the B-complex group, and can be debittered and used in malt extract formulation and for making yeast tablets, yeast slurry and dried yeast make excellent animal feed in poultry, piggery and dairy. Typical analysis of Brewers' yeast is given below:

Nitrogen (on dry basis)	7.88%
Protein (on dry basis)	49.28%
Free moisture	10.85%

Having talked about useful reclaimable by–products, let us turn our attention to the possible pollution, hazards in a brewery and how best they can be controlled and tackled. The inevitable slurries, washings and other discharges of these categories have the following 5 day-BOD values before they enter the main sewer.

	BOD
1. Spent Grain Squeez Liquor	15000 to 25000
2. Hop Press Liquor	7300
3. Yeast Wash Water	7400
4. Beer Filtrate from Yeast	69000
5. Bottle Washing Liquid	870
6. Fermenter Washings (with Yeast)	70250
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5 Day–BOD of Brewery Sewerage 420 to 1350.

Brewery effluents generally give a COD value of about 1.25 to 1.5 times the BOD.

Although the above figures look ominous, the picture suddenly undergoes a change. In a brewery, generally product to water utilisation ratio is 1:12. In this about 2 parts are consumed as product content and evaporation losses. The balance 10 is used for washing, cleaning and sterilisation during the manufacturing and packaging processes. Thus there is an enormous dilution of effluent taking place, which is built into the system, in spite of brewers believing in the dictum 'Dilutions is no solution to pollution'. Generally people club breweries with distilleries and will have the misconception regarding the quality of brewery effluents. As explained above, many of the 'would have been' waste products, can be converted into useful by–products at an economic level.

Removal of spent 'Filter Aids' in solid form and employing them as sanitary land fills is a good practice. In the beer packaging section, a good amount of weak caustic solution and pasteuriser overflow water, enter the sewer, which has a higher pH value. The effluent from Brew House and other processing sections will have a lower pH. By judicious flow balancing, the pH of the final Brewery effluent can be adjusted to the desired levels.

In a few of the very large breweries in America, concentration of Spent Grain Liquor, using centrifuges and submerged combustion evaporator have been in operation. This is to concentrate nutrient bearing Brewery waters and add them back to Spent Grains. Use of hop concentrates and processed hot pellets in place of natural hops is gaining acceptance, which indirectly aids prevention of pollution.

Both collets (broken glass pieces) and label paper pulp from washing machines in a Bottling Hall are products that emerge as waste products. It is upto the Breweries to find ways and means of their disposal, as they can find use as raw materials in glass factories and in paper making.

All direct connections to the main sewer must be provided with an intermediate settling pit, which acts as a holder of solids.

Cleaning-in-place (CIP) system employed throughout the operations help in effective cleaning, low labour costs and allow reuse of water and cleaning solutions, which can be used, until the cleaning power is exhausted, rather than only once.

The strength of effluent and its pollution potential is assessed by the parameters of BOD and/or COD, suspended solids, pH and temperature.

Biochemical Oxygen Demand is the weight of oxygen required by suitable organisms to decompose the organic matter in a period of 5 days at 20°C.

Nitrogenous components are only oxidised, if the test is continued for about 20 days, and the amount of

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oxygen then consumed is termed as U.O.D. or ultimate oxygen demand.

Water can only hold a limited amount of oxygen in solution, upto 10 mg. per litre. If an effluent has an oxygen demand of 100 mg/litre, then every litre of effluent will require 10 litres of water to fully oxidise it.

Brewery effluent is treated more efficiently when mixed with domestic sewage, because the sewage provides nitrogen and phosphorous, which are low in brewery discharges. Issac has pointed out that for rapid and effective biological oxidation of organic matter, there is an optimum ratio of B O D: Nitrogen: Phosphorous of about 100:6:1. As Brewery wastes are low in N and P, admixture with domestic sewage, corrects the imbalance.

In a Brewery, there is always the possibility of reclaiming wort or beer in process, by purge system of filtration, to an extent of 2 to 3 per cent of the total allowable losses, by giving attention to details throughout the process. A total approach to the Brewery effluent problem, will result in reclamation of profitable by-products, which may have gone as waste products, in addition to their fouling up the environment by joining the effluent stream.

As socially responsible partners in industrial progress of the country, brewery companies will always strive hard to reduce the pollution potential of their effluents.

By-products from the Fruit and Vegetable Preservation Industry and the Economic and Safe Disposal of Wastes and Effluents

G. S. Siddappa

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Preservation of fruits and vegetables is an important sector in the agro-industrial complex in several parts of the world that are highly developed or are in the process of development. Based on renewable resources of the land, this industry is of high economic as well as strategic importance, as it helps *i*) in preventing wastage of highly valuable nutritious materials such as fruits and vegetables, *ii*) takes care of gluts during the peak season *iii*) maintains price levels for these highly perishable products and *iv*) makes, fruits & vegetables preserved products easily available to the population, when highly seasonal, fresh fruits and vegetables, are not easily and cheaply available during several months of the year. During their production, however, only the edible portion is prepared discarding large proportions of non-edible materials such as peel, seeds, stones, etc., at different stages of preparation and processing. There is thus left over a large percentage of the original materials that required to be utilised economically. The industry also has to face the problem of solid wastes and their disposal and the safe disposal of waste waters and effluents that are produced in the process of primary preservation and processing of the fruits and vegetables as well as in the secondary processes involved in the utilization of the waste products. Safe disposal of large amounts of final wastes and effluents, assumes critical importance in view of the present day emphasis on prevention of environmental pollution of atmosphere and water supplies leading to health hazards. The fruit and vegetable preservation industry, unlike other food processing industries, is unique in the sense that the proportion of waste materials to be handled is often much more than the preserved edible materials itself. However, there is the advantage that the disposal of these wastes, which are generally biodergradable organic materials, is fairly simple and the likely health hazards are comparatively less, provided simple precautionary measures are taken in the very early stages of the processes.

1. Fruit and Vegetable wastes

Fruit and vegetable canning industries, by and large, contribute large quantities of food wastes as well as some non-food wastes. These are mostly peels, cores and unusable portions of edible materials. These are solid materials with high moisture content. Some of these materials often get mixed up with the water used for cleaning and flushing operations during the regular processing work. The general practice of their disposal has all along been to discharge the materials into the nearby streams, municipal sewerage system or large ponds. In many countries, this has been objected to as possible source of pollution, and Governments have therefore, limited such disposals, necessitating thereby alternative methods of treatment and disposal. The basic regulations with parameters for measuring the level of pollution in discharges to public waters are, by and large, typical of those laid down in the U.S. Federal

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Water Pollution Control Act; Amendments of 1972, administered by the Environmental Protection Agency (EPA). The Biochemical Oxygen Demand (BOD), five day value, Chemical Oxygen Demand (COD), total solids, total dissolved solids (non-filterable), total suspended solids filterable), total volatile solids, total organic carbon (TOC), all expressed in mg/l, and a few others.

There are other regulations and parameters in the case of solid waste disposal.

Although a variety of fruits and vegetables are canned and processed into products in different parts of India, depending upon local conditions, the more important of them include mango, pineapple, orange, guava, apple, peas, carrots, beans, tomatoes and some indigenous materials such as *Parwal*, bitter gourd, lady's finger (okra), etc., During their processing, solid as well as liquid waste occur to varying extents. Some of these are sources for development of by-products of economic importance, resulting in the reduction of cost of production of the main primary processed product which is a highly important consideration in the present day context of the Indian fruit and vegetable preservation industry. A number of attempts, regular as well as innovative procedures, have been tried in several cases to achieve this objective. The results, however, have not yet been spectacular in view of the fact that the Indian processing industry is still small and the scope for developing economic by-products from waste materials still smaller. There are, however, indications, based on experimental results obtained in some of the research institutions as well as factories themselves, that there is scope for developing by products in the case of some of the fruits and vegetables that are being currently processed on a fairly large scale.

The reason for this slow catch-up of by-product development is that the machinery and equipment as well as the technology needed are more complex and costlier than those in the case of the primary processing industry itself. An attempt is made here to pinpoint the present status of development and indicate feasibility of future development in the case of a few typical fruits and vegetables with the hope that this could serve as a guide line in the case of others.

The approximate amounts of peel, core, trimmings, seeds, etc., that arise as wastes in the case of some of the typical fruits and vegetables are shown in the following table.

Fruits and Vegetables Industry—Solid Residuals in Canning, Dehydration and Freezing.

Item No.	Fruit/vegetable	Nature of wastes	Waste as % of original raw materials
1.	Mango	Peel, stone, trimmings	25–30
2.	Pineapple	Crown, peel, core, eyes, trimmings, pomace from juice.	45–50
3.	Orange	Peel, seeds, pomace from juice.	50–55
4.	Lemon	Peel, pomace, seeds,	40–45
5.	Guava	Peel, seeds, core	40–45
6.	Apple	Peel, core, trimmings, pomace from juice	30–35
7.	Peach, apricot, pear	Stone, peel, core, pit	20–25
8.	Tomato	Skin, core, seeds, trimmings	8–10
9.	Peas (Garden)	Shells from pods	20–25
10.	Beans (Green)	Stalks, strings	15–20
11.	Carrots	Stalk ends, tips, trimmings and scrapings	5–7
12.	Miscellaneous vegetables	Trimmings	20–25

2. Disposal of Solid Wastes—General Considerations

In the USA and elsewhere, the major portion of the solid wastes is utilized as animal feed. Citrus wastes are treated and converted into animal feed. Peel, pulp and seeds are distintegrated, partially neutralised with lime and pressed to separate the liquor, which is subsequently concentrated to molasses, recovering the oils from the vapours. This molassses concentrate is mixed with the solid press cake and dried in a rotary dehydrator. The dried material is powdered and utilised directly as cattle feed. Lemon peel and pomace are utilized for the recovery of high grade pectin. Most of the fruit and vegetable wastes are, by and large, converted into animal feeds. Apple wastes are processed into vinegar, Apricot pits yield almond paste substitute and an abrasive cleaner and so also peach pits. Harvesting waste residuals such as pea vines and pods and root crop tops are either ploughed into the field or baled for use as animal feed. Other unusable solid wastes are generally spread out on agricultural land taking precaution to guard against, potential water pollution. In some factories in India, citrus wastes, pineapple wastes and mango wastes are spread out thinly on agricultural land, and cattle and pigs allowed to graze so that there are not any large scale insect, rodent and odour problem. This is, however, a *laissez faire* policy leading to no visible income to the unit. However, it is better to utilise these materials for processing into economically profitable by-products.

3. Liquid Wastes

In the fruit and vegetable canning industry, although only small portions of the solid residues get mixed up with water during the processing operations, the dis-

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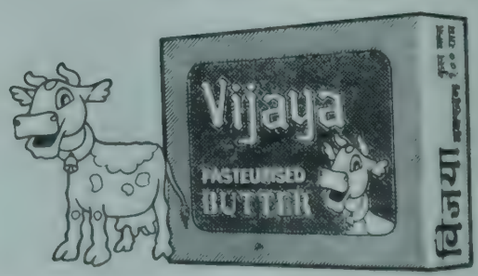

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posal of this liquid waste presents a serious problem technically as well as economically, especially in view of modern pollution control requirements and the high cost of treatment. Under these circumstances, it is preferable to minimise the contamination itself and also to minimise the use of fresh water in the processing operations, thereby reducing the quantity of waste water to be treated in the municipal or processor-operated treatment plants. As far as possible, all solid residues should be handled separately instead of flushing them down the drains with jets of water as in the washing of processing hall floors, work tables etc. Accumulated wastes inside the factory should preferably be swept up, collected in dry containers or dry conveyors. As for as possible, all solid organic materials should be kept out of the waste water. Equipment is first cleaned with used water, but rinsed with fresh clean water. In recent years, the need for conservation of fresh water and reduction in waste water discharge has lead to technological developments such as reduction of water in product preparation, screening and recirculation, cooling of packed jars in an evaporative system, partial treatment of waste water, possibility of dry caustic peeling instead of with hot lye solution which requires large quantities of sugar, reuse of can cooling water after screening and adequate sanitization, recirculating it through a cooling tower, etc.

4. Waste Water Treatment and Disposal

All coarse particles should be screened on rotary or vibrating sieves before the waste water is subjected to further treatment. This was the practice that was being successfully adopted at the Fruit and Vegetable Canning Research Station, Campden (Glos) England. In India the waste water is allowed to flow down into the sewerage treatment plant directly, in the open agricultural land, and in some cases to a settling tank with retention for a few hours prior to overflow to remove most of the solids with consequent reduction in BOD. The sediment should be removed occasionally. The subsequent and secondary treatment is of biological nature whereby organic wastes are converted into volatile gases methane, carbon-di-oxide, nitrogen and insoluble sludge. The effluent will be suitable for return to water ways. Another secondary method is to make use of large shallow ponds where microbiological conditions, aerobic as well as anaerobic, reduce the BOD, clarify the liquid sufficiently to be run off into main stream, without pollution hazards. Growth of algae and providing mechanical aeration will be useful in settling up aerobic conditions thereby overcoming development of putrescent and offensive odours.

In the activated sludge process, aeration of the liquid in a pond is necessary to remove the organic matter and form an insoluble sludge, which generally settles down. This system, which is satisfactory for the treatment of domestic sewage, when used for the treatment of cannery wastes, requires the addition of nitrogen and phosphorus compounds or mixing with domestic wastes, for satisfactory working. The biological trickling filter, which allows the water to trickle over crushed stones, has been found quite effective for long term operation in the case of domestic sewage. Bacteria, fungi and algae grow on the filter, remove the BOD and render the effluent quite clear. This was being successfully adopted at the Campden Research Station (Glos) England, the clear effluent being subsequently utilised for irrigation and growing of vegetables. Since cannery wastes are seasonal and require quicker disposal and also lack in adequate nitrogen, the trickling filter is not quite effective for their treatment.

5. Land Disposal

Where very large quantities of waste water are required to be treated and disposed of, land treatment is perhaps the cheapest and best. There are several types of disposal on land, such as row and furrow irrigation, sprinkler system, overland flow, slow or rapid infiltration, intermittent application followed by rest periods, alternating disposal areas in the field, etc all of which have been successfully employed. For details one may look up paper by Hunt and Glide, 1976[1] and Publication No. 39 California State Water Resources Control Board, Sacramento, 1968[2].

6. Development of Some Useful By-products from Cannery Wastes

In our country, a number of workers have attempted to develop useful by-products from wastes of fruit and vegetable canning and dehydration plants. Large scale development of a few of the processes has not yet been possible on account of the smallness as well as the scattered nature of the main industry. It will be useful to look into the possibility as well as the feasibility of some of the developments in the case of commercially and industrially important fruits and vegetables.

6.1. *Mango:* This being the premier fruit of India, it is utilized for canning in the form of slices, pulp, juice, jam, and for the preparation of beverages such as squash, nectar, etc. The unripe green fruit is employed in the preparation of chutney and pickle both of which are well known, peel and stone are the more important waste products. It has recently been found that a syrup of good quality could be prepared from the peel which contains adhering pulp[3]. The kernel is a rich source of starch which is recovered sometimes on a small scale as a cottage industry. The more important constituent is the kernel fat which has become prominent on account

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of its suitability for substituting cocoa fat in confectionery manufacture[4]. When collection of stones from the canning factories is systematically organised, it might be possible to recover the starch as well as the fat, both of which are of economic importance. The residues could be turned on to the land as manure or burnt as fuel.

6.2. *Pineapple:* Canned pineapple products such as slices, titbits, juice and pulp are packed in the country on a fairly large scale for export as well as domestic distribution. Nearly 50 percent of the fruit in the form of peel, core, eyes and trimmings is discarded as waste. These waste materials could be utilized to develop profitable by-products. We have carried out a series of experiments on the use of the core for the preparation of an excellent candied product which resembles candied bamboo shoot in several respects. In the form of cylindrical pieces, ½ to ¾ inch in diameter and ½ inch in height, this product is an important byproduct of the pineapple canning industry. The peel and the trimmings could be minced and pressed to yield juice which could be converted into a thick syrup by concentration, or demineralised on exchange columns and used to supplement the covering sugar syrup for canning the slices and titbits. Some work has already been reported on this aspect. Further intensive work is, however, needed to commercialise the process. The press cake could be suitably treated and converted into animal feed. At present, this material is spread out thinly on land, and animals consume it readily.

The pineapples are harvested and delivered to the factory with the crown and the stem intact. These are cut off at the factory before peeling and slicing the fruits. The crown can be sold to prospective pineapple growers, while the short piece of stalk or stem could be converted into manure. In the field itself the larger leaves of the crown could be utilised for the preparation of fibre as is being done in some areas under the auspices of the Khadi and Village Industries Board. Pineapple being a source of the enzyme bromelin, it may be possible to extract it from the waste. The possibility of making animal feed from the peel, core and trimmings as in the case of citrus fruit should be explored systematically.

6.3. *Citrus fruit–orange and lemon:* The peel removed for canning orange segments can be successfully utilized for extraction of cold pressed orange oil which has a premium value. The double or triple roller press which has been developed at the Central Food Technological Research Institute, Mysore, or other commercially available equipment could be employed for this purpose. From the peel emulsion obtained, the peel oil is separated by means of a centrifuge of the Sharples or Alfa-Laval type. The income from this oil alone will reduce considerably the cost of the canned product. When orange juice is extracted from the unpeeled and cut halves of the fruit, the extracted cups contain the pomace adhering to the peel. It is necessary to scoope this out before the peel cups could be utilised for extraction of the peel oil. Prior treatment of the cups with lime water is necessary to harden the peel and render it suitable for extraction of oil on the roller type of machine. After extraction of the oil, the residual peel, together with the pomace scooped out earlier, could form the basis for pectin production. Alternatively, the peel, pomace, seed material and any rejected fruit could be disintegrated, partially neutralised with lime, pressed, concentrated and converted into dry cattle feed as is the practice in the U.S.A. and elsewhere.

The lemon peel and pulp have been found useful for the preparation of pectin of high quality as per the process developed by the Central Food Technological Research Institute, Mysore. The orange and also lime seeds could be utilised for extraction of oil for industrial use. When lime or lemon juice is stored for settling to obtain clear juice, for the preparation of lime juice cordial, considerable amount of sludge settles down. This solid waste material also could be utilised for the preparation of pectin and recovery of lemon/lime peel oil.

6.4. *Other fruit wastes:* In the case of apples, the waste material is largely utilised for making apple vinegar or cider vinegar. Dried apple pomace is an important raw material in the manufacture of apple pectin in liquid or powder form in some of the contries that process apples into juice, cider, canned slices and rings, dehydrated rings, etc., on a large industrial scale. Apple pectin and apple vinegar manufacture as by-products could be attempted in Himachal Pradesh, Kashmir and elsewhere apples are processed into juice and cider and the juice concentrated on a fairly large scale.

Guava peel, trimmings and seeds could be extracted and converted into marketable products such as guava cheese, jelly, etc.

Banana peel is another waste material suitable for making a fruit cheese-like product. From the harvested stem, starch and fibre could be extracted as has been demonstrated by the exploratory work at the Central Food Technological Research Institute, Mysore. In general, most of the wastes from fruit processing industries are suitable for the manufacture of cattle feed, when the processing industry is on a sufficiently large scale to yield adequate quantities of waste material.

6.5. *Vegetable wastes:* In the case of vegetables such as peas, beans, beet root, etc., the major portion of the waste occurs at the harvesting end in the form of vines, stalks, pods, crop tops, etc. These are generally used in the fresh condition for feeding cattle or ploughed into the field to serve as manure. It might be possible to convert them into silage. In the case of green tops from root crops it might be possible to extract chloro-

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Phyll as in the case of papaya leaves left over after harvesting the green fruits for the manufacture of papain and also pectin as in the case of the integrated process developed at the Central Food Technological Research Institute, Mysore for recovery of papain and pectin. Very little work has, however, been done in regard to the recovery of the green pigment chlorophyll. There have been proposals in some countries to raise papaya plants with close planting, to extract chlorophyll, papain and some other chemicals from the whole plant as such without waiting for the plant to bear fruit. A similar suggestion was made by the author while at CFTRI for growing banana plants in close plantings, for starch, fibre and paper pulp only and not necessarily for fruit[5].

In the processing of tomatoes for juice, ketchup or sauce, the main utilisable waste is the seed which is in demand. The other waste is the peel together with core and trimmings to the extent of 8 to 10 per cent. This could be pressed and dried for use in cattle feed or soup stock.

7. Importance of By-product Development from Wastes

The economic success of any industry in general, and the fruit and vegetable industry in particular, depends to a large extent on the utilization of the waste products that arise during the various stages of processing[6,7]. Large quantities of non-edible materials such as peel, stone, core, trimmings etc. are, left over after preparation of the primary edible material. These are mostly thrown away thereby losing valuable material suitable for development of profitable by-products that could bring in additional income to the industry and also reduce the cost of production of the primary products. Further, the disposal of large quantities of the waste as such will create pollution problems in regard to the atmosphere, water supplies etc. and also sometimes result in health hazards, when the materials are handled indiscriminately. In recent years, environmental pollution problems have come to the forefront and require solution at various levels. In this context, it will be highly desirable for the fruit and vegetable preservation industry and also other food processing industries involving milk, fish, meat etc., where the disposal of the wastes, solid as well as liquid, is a more serious problem in regard to environmental pollution and health hazards, to initiate as well as intensify efforts to develop by-products from wastes for profit and at the same time minimise environmental collution and health hazards. The motto should be "Wealth from Wastes, with Cleaner Environment".

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By-products from Plantation Crop Processing Industries

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Plantation products form an important source of foreign exchange earning to the country. Effective utilization of natural resources is very essential for the development of the plantation industry. The problems of environmental pollution has also figured in a number of instances especially from coffee pulp washings and with the development of other processing industries. One should reduce such pollution problems to the minimum.

With the cost of production of the main commodity on the increase it is but essential that we should employ systematic approach to utilise in its entirety the natural products so that our products will be competitive in the world market. In this connection, by-product utilisation and utilisation of wastes become very important and this paper reviewes the utilisation of various possible by-products based on their composition.

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TABLE 1. PLANTATION CROPS—AREA, PRODUCTION AND EXPORT OF IMPORTANT ITEMS

Crop/Produce	Year	Area (Ha)	Production (M.T.)	Product	Year	Export (M.T.)	Value ('000 Rs.)
Black pepper	78–79	112000	26000	Black pepper	77–78	25249	500531
Dry chillies	78–79	805000	638000	Dry chillies	,,	4610	40153
Dry ginger	78–79	35000	67000	Dry ginger	,,	9464	136443
Turmeric	78–79	82000	147000	Turmeric	,,	9319	71892
Cardamom	78–79	96000	4600	Cardamom	,,	2825	485483
Onions	78	215000	1590000	Garlic	,,	2464	8852
Garlic	78	37000	140000	Spice oils	,,	7.67	3003
Oranges	78	—	1037000	Spice oleoresin	,,	131	19214
Lemon & Lime	78	—	453000	Cashew kernels	,,	23820	752100
Grape fruit & Pommelo	78	—	20000	CNSL	,,	5001	34774
Other citrus fruits	78	—	29000	Arecanut	,,	522	6809
Cashewnuts	78	417296 (1976–77)	157200	Coffee	,,	55827	2304589
Coffee	78	180000	119000	Tea	76–77	242418	2952577
Cocoa (dry beans)	79	—	1000	Instant tea	76–77	583.66	25065
Tea	78	365000	565000	Citrus fruits	76–77	4640	—
Coconuts	77–78	1082900	4370000				
Copra	78	—	329000				
Tapioca (cassava)	78	388000	6493000				
Arecanut	77–78	175500	170300				

Sources: 1. Indian Spices, Vol. XV (3), 1978, p. 16.
2. Agril Situation in India, Jan. 1980 & April 1979.
3. FAO Year Book of Production 1978.
4. Indian Coffee: Vol. XLIII (12), 1979.
5. The Planters' Chronicle, June 1979.

cacao, cassava, coffee, citrus fruits, rubber, spices and tea. India earns considerable amount of foreign exchange every year by the export of plantation products (Table 1). The plantation crop processing industries can get more money if their wastes or by-products are put to better utilization. An attempt has been made here to give a brief account of the utilisation of wastes or by-products of the plantation crop processing industries. Various products that can be obtained from the by-products of plantation crop processing are given in Table 2.

1. Arecanut

Arecanut is an important plantation crop of Karnataka, Kerala, Assam and Meghalaya. The fruit contains a hard nut about 15-25 mm in diameter. The nut is cut into pieces and chewed along with lime and betel leaf. The seed or nut is enclosed in an endocarp of fibrous husk. India now produces about 0.17 million tons of arecanut from an area of about 175000 hectares. The growth rate of internal consumption is not keeping pace with the growth rate in production. This product has not much export potential. Therefore, the cultivation of arecanut is adversely affected. Now, efforts will have to be intensified on the following lines: (1) finding alternative uses for arecanut other than chewing and (2) commercial utilization of wastes/by-products of this crop. The by–products of arecanut are areca husk, leafsheath, leaves, chogaru liquid or kali.

1.1. *Arecanut husk:* It is a by-product obtained during the dehusking of the nut. About 600-700 kg. of arecanut husk can be obtained/hectare of arecanut crop. The total quantity of dry husk now available in the country may be nearly one lakh metric tonnes.

The chemical composition of the arecanut husk is comparable to that of straw and wood. Therefore, materials like low density fibre boards, and high density hard boards can be made from areca husk. Pilot plant

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TABLE 2. PRODUCTS FROM BY-PRODUCTS OR WASTES OF PLANTATION CROPS

Produce or crop	Main product	By-product/waste	Possible by-products
Coffee berries	1) Coffee beans or coffee seeds 2) Decaffeinated coffee seeds	Pulp and husk, hulls, mucilage, caffeine, spent grounds.	Feeds, caffeine, protein, vinegar, enzymes, biogas waxes, feeds, fuel, charcoal, acetic acid, pectic enzyme, pectin, feed stuffs, drugs, coffee oil.
Tea	Black tea, green tea, instant tea.	Waste tea, tea seeds.	Caffeine, polyphenols, pigments, n-triacontanol, manure, furfural, feeds, waxes, seed oil, cake, protein, saponins.
Areca	Arecanuts	Areca husk, chogaru/kali, arecanut fat, leaf sheath, leaves.	Mattress, tannins, cooking oil, detergents, cups, boards, lining material, brooms, manure, fuel.
Cashew	Cashew kernels	Cashew apple, cashew testa, shell liquid (CNSL)	Beverages, juices, liquor, tannins, lacquer, resins, varnishes.
Cassava (Tapioca)	Tubers	Rind/peel/bark, seeds.	Protein, amylases, oil, animal feeds, protein.
Coconut	Raw coconuts, copra, coconut oil, dessicated coconut.	Coir, coir dust, shell, coconut water, coconut sap.	Mattress, floor coverings, roaps, insulation slabs, boards, moulded articles, fuel, fancy articles, charcoal, carbon, shell flour, furtfural, growth medium, coagulant, drinks, toddy.
Cocoa	Cocoa beans	Empty pods (husk), cocoa shell, cocoa germ, shell-nib mixture.	Cattle feeds, manure, theobromine, shell butter, fuel, vit.A, germ-fat, fat.
Citrus	Citrus fruits, juices	Essential oils, pressed peel, pressed liquor, seeds, fruit pulp.	Terpenes, terpeneless oils, soft drinks, food flavourings, perfumery, citrus pulp and meal, stripper oil, molasses, pectin, colours, seed oil protein animal feed, jams, jellies, bases for soft drinks.
Rubber	Rubber	Seeds	Seed oil, seed cake, soap, paints, varnishes, protein.
Spices	Raw spices, mixtures, spice oils, spice oleoresins.	Spent spices/material, ginger-peels, leaves.	Starch, cellulose, colours, ginger-peel oil, cinnamon leaf oil, eugenol, chemicals.

studies at the F.R.I. Dehradun, have shown that brown wrapping paper can be prepared from the husk if mixed with bamboo and jute pulp. Insulating boards and insulating wool can also be prepared from areca husk. Areca husk can be used in the manufacture of rubberised mattress similar to rubberised coir mattresses or it can be even blended with coir..

1.2. *Leaf sheath and leaves:* The total quantity of these wastes available in the country is roughly estimated to be about 90,000 tons per year. A portion of this may be used as thatch. A still smaller portion is used to prepare brooms (from mid rib of leaves). The rest goes as waste or used as fuel. The chemical composition (Table 3) shows that they have certain potential manurial value. The areca husk is a highly lignified material. Leaf sheath can be utilised for preparation of boards, lining material for boxes, shoes, etc. CFTRI, Mysore, has developed a machine for making cups *(Donne)* out of areca sheath.

TABLE 3. CHEMICAL COMPOSITION OF ARECA LEAF SHEATH AND HUSK

Constituent	Leaf sheath	Arecanut husk
Moisture (%)	11.00	5.00 – 10.00
Pectin (%)	—	0.92 – 3.33
Pentosans (%)	—	14.80 – 19.05
Cellulose (%)	43.15	37.00 – 49.00
Lignin (%)	—	17.58 – 24.98
Ash (%)	4.99	4.07 – 6.30
Crude fibre (%)	30.94	— —

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1.3. *Chogaru liquid or 'Kali':* It is the residual liquid obtained after boiling tender nuts in water. The sediments, which are found in this liquid, when freed and dried become arecanut dust. These by-products are rich in tannin and can play an important role in the leather industry. But it would be necessary to ensure a constant and steady supply of these materials at economic cost before the tanning industry can use them regularly.

1.4. *Arecanut fat:* Arecanut, although not an oil seed contains fat. The arecanut fat which is a solid has a potential for substituting imported tallow and cocoa butter to a certain extent. Arecanut when extracted with normal hexane can yield 11% fat. It is a white plastic solid (m.p. 38.5°C) and is easily refined and bleached. It can be used for cooking purposes also. Being rich in saturated fatty acids, the crude oil could have demand in soap and surfactant preparations. It is rich in lauric (20.8%), myristic (38.5%) and palmitic (16.4%) acids.

2. Cashewnut

Cashew is an important plantation crop of India. The production of raw cashew nuts in India is estimated to be nearly 1,80,000 tons and processing of cashewnuts is the largest agrobased industry in Kerala employing about 1.5 lakhs of persons directly. The annual export of cashew kernels ranges from 20,000 to 50,000 MT. The important by-products of cashew are (1) cashew apple (2) cashew testa and (3) cashewnut shell liquid (CNSL).

2.1. *Cashew apple:* It is estimated that about 10 lakh tons of cashew apple are available annually. Because of its astringent taste and fibrous texture, only a small quantity of the production of cashew apple is consumed locally and a major portion is wasted. The chemical composition is given Table 4. About 65% of the juice can be obtained from the apple by extraction. The juice, after removal of astringent and acrid principles has been found to be suitable for a variety of beverages like clarified juice, cloudy juice, juice blended with lime, orange, apple, pineapple, juice concentrates, spiced juice and also for the manufacture of liquor (Feni) in Goa. Cashew apple can also be used for the preparation of cashew apple candy, syrup, canned cashew apple, fruit *chutney*, curried vegetable, pickles, etc. CFTRI, Mysore has worked out details of all the possible uses for cashew apple.

TABLE 4. CHEMICAL COMPOSITION OF CASHEW APPLE

Constituent	Per 100 g
Moisture	86.20
Protein	0.80
Fat	0.60
Minerals	0.40
Fibre	0.90
Carbohydrates	11.90
Calories	53
Vitamin 'A' (I.U.)	39
Thiamine (mg)	0.02
Riboflavin (mg)	0.05
Nicotinic acid (mg)	0. 4
Vitamin 'C' (mg)	180

Cashew apples are collected from the farm after removing the nuts. As the skin of the fruit is very tender, it gets bruised very easily and leads to rapid fermentation and it cannot be stored for long. Because of the scattered nature and small size of the individual plantations, collection of the apple poses a real problem. In Goa, nearly 40,000 tons of cashew apple are being used for the production of liquor both, under crude and modern methods.

2.2. *Cashew testa:* The brown thin skin covering the cashew kernel is called the cashew testa. It is a by-product of the cashew processing industry. At present it is mostly wasted or used as manure in agriculture. When it is infested, it is a nuisance in the cashew factories.

The testa contains 42.5% of total extractable solids and 32% total phenolics when extracted with aqueous acetone. Chromatographic studies show that the main constituents are catechin and epicatechin each account for 6.0-7.5% of the cashew testa. Together, they represent more than 40% of the total polyphenols. The chemical analysis shows that the testa is a good source of catechin type of tannins. Annually, about 2,60,000 tons of raw cashew are processed in about 250 processing factories in India. This roughly comes to about 2600 tons of cashew testa.

Cashew testa is a good source of tannin but at present it is not being exploited at all in the country. The Indian leather industry is mostly depending on imports to meet its requirements of tannin extracts. India spends about 2.24 crores annually for importing tannin extracts. A unit for the commercial production of tannin from cashew testa has been recently set up in Quilon district of Kerala State.

2.3. *Cashew shell liquid (CNSL):* The reddish brown viscous liquid inside the two layers of the cashew shell is a versatile industrial raw material. It consists chiefly of the two naturally produced phenolic compounds—anacardic acid (~90%) and cardol (~10%). It derives its value from the fact that it lends itself easily to polymerization. The major applications of CNSL are in the manufacture of cashew lacquer, cashew cements, laminating resins, rubber compounding resins,

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brake linings, intermediates for chemical industry, epoxy resins, foundry cehmicals, insulating varnishes, electrical windings, chemical conductors, coating compositions, water and weather proofings etc. It is estimated that out of 10 to 15 thousand tons of CNSL produced in the country, only 1000 tons are used in the country due to various reasons: (1) Inadequate research work done on the possible utilization of CNSL. (2) Lack of extension work by research institutions, etc. As there is less demand from outside, the use of CNSL in the country has to be increased in foundry, automobile, paints, varnishes, railways and defence establishments.

Cashewnut shell can be an economic raw material for the production of D-galactose in place of the costly material milk sugar currently used. D-galactose is a rare sugar used in the pharmaceutical industry (for testing liver function, etc.) and 100 kg of D-galactose are obtained from three tons of cashew nut shells.

The shell contains about 24-35% of CNSL but only 10-20% of the CNSL is being recovered by the oil bath method and the balance quantity is left over and utilised as fuel. By introducing the solvent extraction method a good quantity of the remaining CNSL in the shell can be extracted. It has been suggested that the shells without CNSL could serve as a raw material in the manufacture of plastics and container board.

3. Coconut

The coconut palm is rightly called *Kalpavriksha* (heavenly tree) or the tree that provides all necessities of life. Because it not only supplies substantial quantity of food but also provides raw material for a number of industries. There are many industries which directly or indirectly depend on coconut palm. The soap, vanaspathi and perfumery industries utilize coconut oil. The coir industry which utilizes coconut husk, is earning considerable foreign exchange for the country. Excepting copra and coconut husk, there are a number of wastes/by–products such as pith, shell, water, stem, leaves, buttons, spathe, etc., which remain economically unutilized.

3.1. *Coir dust:* It is the waste left over after extraction of fibre from coconut husk. This light fluffy refuse is a mixture of corky pith, fibre shorts and pericarp. It constitutes nearby 50-60% of the weight of the husk. It accumulates in abundance in the coir extraction centres in the coastal areas of South India. About 1,60,000 tons of pith is annually available in the country. No proper use has been found out for this and it is thrown in the back water edges. The coir dust contains about 12% moisture and 88% dry matter. The chemical composition is given in Table 5.

Coir dust has been found to have limited agricultural uses. It is an excellent soil mulching material for coconut nurseries and in citrus culture. It absorbs as much as eight times its weight of water with which it parts fairly slowly. Coir dust has little manurial value.

TABLE 5. CHEMICAL COMPOSITION OF COIR DUST (GENERAL)

Constituent	% on wet basis	% on dry basis
Organic matter	8.40	9.13
Mineral matter	7.70	8.70
Fats & Resins	1.60	1.80
Cellulose (Cl method)	30.80	35.00
Lignin (72% H_2SO_4method)	22.20 29.30	25.20 33.30
Pentosans	6.50 9.20	7.40 10.40
Nitrogen (as N)	0.26	0.30
Protein (N×6.25)	1.70	1.90
Loss on boiling in 1% NaOH for 5 min	10.60	12.00
potash (K_2O)	0.79	0.90
Phosphorus (P_2O_5)	0.04	0.05
Calcium (CaO)	0.35	0.40

Some of the industrial uses of coir dust are: (1) Insulation slabs for use in air conditioning and refrigeration. (2) Boards from coir wastes. (3) Expansion joint filler. (4) Manufacture of moulded articles. (5) Furfural production. Inspite of the potential uses, disposal of coir dust still remains a problem in many places. Exceedingly moist nature of the material and its saline content are the main problems in the utilisation of the coir dust.

3.2. *Coconut shell:* It is the endocarp of the coconut fruit. It is available in large quantities near copra making centres or dessicated coconut manufacturing establishments. In India, the estimated annual production of shell is 0.88 million tons, out of which 50% can be economically collected in the country. The chemical composition of coconut shell is given in Table 6.

TABLE 6. CHEMICAL COMPOSITION OF COCONUT SHELL

Constituent	Per cent
Moisture	6.76
Ether extract	0.17
Alcohol-benzene extract	1.98
Ash	1.32
Hot water extract	1.76
Pentosans	30.01
Lignin	32.22
Cellulose	50.99

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TABLE 7. CHEMICAL COMPOSITION OF COCONUT WATER

pH	4.8 to 5.3
Water (%)	95.5
Total solids (g/100 ml)	4.7
Nitrogen (%)	0.50
P_2O_5 (%)	0.56
K_2O (%)	6.60
Reducing sugar as invert sugar	0.80%
Additional reducing sugars after inversion as sucrose	1.28%

Some of the potential uses of coconut shell are: (1) fuel in kitchen, laundries, smitheries, bakeries, lime kilns, brick yards, etc., and (2) manufacture of fancy articles. Industrially, it can be used for the production of (1) coconut shell charcoal (30% of shell), (2) activated carbon, (3) coconut shell flour (100-500 mesh), (4) furfural production. Destructive distillation of 1000 kg. of coconut shell can give 300 kg. of charcoal, 300 kg. of gas, 50 kg. of tar and 350 kg. of pyroligneous acid.

3.3. *Coconut water:* Large volumes of coconut water from the ripe nuts are run off as waste product of copra manufacture. The estimated quantity is about 0.5 million tons. 200 nuts yield about 100 litres of water. As no economical process has so far been developed for economic utilization of coconut water, presently it may be treated as waste. The chemical composition of coconut water is highly variable (Table 7). The comparatively low sugar content makes it unsuitable for the manufacture of either sugar or alcohol. The sugar syrup which has been prepared from water, on account of its high salt content is not very palatable. But its other uses could be: (1) as a growth media, (2) as a rubber coagulant, (3) as a rich source of potassium in agriculture, and (4) as a soft drink. But preventing the coconut water from deterioration in quality and proper packaging are the main problems in large scale collection of coconut water.

3.4. *Toddy:* Toddy is prepared by natural fermentation of the sap obtained by tapping the inflorescence of the coconut palms. About 1400 ml of toddy is obtained per tree per day on an average. The composition of toddy is given in Table 8. Proper preservation and standardisation are the important problems associated with toddy.

TABLE 8. COMPOSITION OF TODDY

Item	Value
Specific gravity, 27°C	1.058 to 1.077
Freezing point	–2.85 to –2.95
Total solids (g/100 ml)	15.2–19.7
Sucrose (g/100 ml)	12.3 to 17.4
Ash (g/100 ml)	0.11 to 0.41
Proteins (g/100 ml)	0.23 to 0.32
Vitamin-C (mg/100g)	16 to 30

4. Cocoa

Cacao is becoming an important plantation crop of India. The production of cacao seeds (cocoa) is nearly 1000 tons per year and it may reach 10,000 tons per year by 1985. The cacao pods are generally made up of husk (80%), pulp (7%), cuticle (1.8%) and kernel 10%. The cocoa beans are the important product and the by-products are the pod walls (husk), shell, germ and the shell-nib mixtures.

4.1. *Pod wall (husk):* As the pod wall is a waste product, very little interest has been evoked in its composition. The pod wall accounts for nearly 76% of the whole fruit and its moisture content is nearly 86%. The total sugars at maturity amounts to 1.62% (glucose 0.35%, fructose 1.03% and sucrose 0.24%) and the content of glycoside glucose is 0.12%. The balance of alcoholic extract due to non-sugars is 2.48%. The ash content is 1.2% and the starch content is 0.05%. The remainder of the solid matter consists largely of mucilage. Research is required for the better utilization of this waste product. We have to find out whether it can be used as a cattle feed or manure.

4.2. *Cocoa shell:* It is estimated that nearly 100 tons of cocoa shell are available in India. The roasted cocoa beans are made up of cotyledons 86.7%, germ (radicle) 0.8% and shell 9-13%. The fat (shell butter) content of commercial shell is variable and fluctuates according to the amount of fat transferred from the nibs through roasting and the efficiency of the winnowing machine in separating nibs from shell. The chemical composition of shell is given in Table 9. On account of high acid value, shell butter is not acceptable as human food. The unsaturated acids in the glycerides of shell butter is 31.9 to 40.5% of oleic acid and 7.8 to 14.5% of linoleic acid; 57.8% of the total protein is digestible. The digestibility is reduced by high roasting. Although shell contains only about 1% theobromine,

TABLE 9. CHEMICAL COMPOSITION OF COCOA SHELL

Constituent	Per cent
Protein	13.5 – 14.12
Ash	6.5 – 8.1
Fat	3.0 – 3.4
Moisture	3.8 – 11.00
Crude fibre	16.50 – 18.60
Pentosans	6.00 – 7.00
Tannins	5.0 – 9.00
Theobromine	0.75 – 1.30
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Pectic acid ,,	4.5
Crude cellulose ,,	20.6

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this is sufficient for profitable extraction on commercial scale. Owing to its high cellulose content, cocoa shell is unsuitable for human consumption.

The value of shell as a feeding stuff is limited by the presence of theobromine; daily intake of theobromine should not exceed 0.025 g/kg body weight. Horses die when the intake is 0.027 g/kg. body weight and upwards.

Shell is used as fertilizer and fuel. The fuel value is 4000 calories per kg. The ash contains 10-12% of phosphate. Cocoa shell can be used as a filler for thermo setting resins in the plastic industry. Commercial extraction procedure for theobromine from cocoa shell is available and extraction could be an important industry.

4.3. *Cocoa germ:* Cocoa germ oil has a high acid value and contains a considerable amount of unsaponifiable matter. 100 g. of the material (oil) contains 825 to 1400 I.U. (or 189-311 μg) or provitamin-A. Cocoa germ constituents are given in Table 10. Potash is the main mineral content of germ (37% in ash). Germ fat is dark coloured and has an unpleasant taste and smell unless subjected to refining treatment. Cocoa germ contains sufficient theobromine to repay its extraction.

4.4. *Shell-nib mixtures:* The composition of the mixture is given in Table 11. The composition of shell-nib mixture depends on the efficiency of the winnowing machine. When the fat content of nib-shell mixture is sufficiently high, it is worthwhile to remove it by pressing. The residue remaining after solvent extraction contains only about 1% of fat and is known as cocoa cake meal. It contains 2-3% of theobromine most of which can be extracted for use in medicinal preparations.

4.5. *Theobromine:* Theobromine forms soluble salt with sodium or calcium hydroxides and magnesium oxide. These alkaline substances can be used to extract theobromine from by-products of the cocoa and chocolate industry. Only a comparatively small portion of theobromine extracted from cocoa by-products is used directly in medicinal preparations. The bulk of it is converted into caffeine by methylation.

TABLE 10. CHEMICAL COMPOSITION OF COCOA GERM

Constituent	Percent
Moisture	7.0
Fat	3.5
Ash	6.5
Protein	24.5
Crude fibre	2.9 to 5.26
Pentosans	2.3 to 2.9
Theobromine	3.0
Provitamin-A	189–311 μg (825 to 1400 I.U.)
Dextrose	0.44
Sucrose	2.15
Caffeine	0.21

TABLE 11. CHEMICAL COMPOSITION OF COCOA SHELL AND NIB MIXTURE

Constituent	Percent
Moisture	5.00
Fat	10 to 38
Protein	18 to 22
Crude fibre	8 to 12
Carbohydrates	30 to 50
Theobromine	1.5 to 2.5

5. Coffee

Coffee is grown for its beans which after roasting are used to make a very pleasant brew. The beans are obtained from within the coffee fruits or berries. In berries, about 29% of the dry weight is represented by coffee pulp, 12% by coffee hulls, 55% by coffee beans and approximately 4% by mucilage. The distribution of the main fractions of coffee berries is given in Table 12. There will be a loss of about 16% when green coffee is roasted and 7.5g of roasted coffee is utilized to prepare a cup of coffee. From this, about 1.8 g of solids (23.5%) are recovered per cup, most of it being infused residue. 1000 kg. roasted coffee powder would result in 600-700 kg. of spent coffee grounds from which we can get 100-150 kg. of oil, 150 kg. of protein and 8 kg. of ash. The important byproducts of coffee berries are the pulp, the hulls and the mucilage. Caffeine is present in most of the by-products of coffee berries as well as in coffee beans. Caffeine can be obtained as a by–product in decaffeination process.

5.1. *Coffee pulp and husk:* The moisture content of the pulp is very high (75%) but the dried material (husk), however, has about 10% moisture. It is also interesting to note that the chemical composition of the fermented and dehydrated coffee pulp is very similar to dehydrated and non-fermented coffee pulp. The chemical composition of coffee pulp is given in Table 13 and 14. Many processes have been designed to render coffee pulp suitable for animal feeding either in the form of

TABLE 12. PERCENTAGE DISTRIBUTION OF THE MAIN FRACTION OF COFFEE BERRIES ON DRY WEIGHT BASIS

	Arabica	Bournbon	Mixture
Pulp	26.5	29.6	28.7
Hulls	10.0	11.2	11.9
Mucilage	13.7	7.5	4.9
Coffee beans	50.0	51.7	55.4

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TABLE 13. CHEMICAL COMPOSIITON OF COFFEE PULP

	Fresh	Dehydrated	Naturally fermented and dehydrated
Moisture	76.70	12.6	7.9
Dry matter	23.30	87.4	92.1
Ether extract	0.48	2.5	2.6
Crude fibre	3.40	21.0	20.8
Crude protein	2.10	11.2	10.7
Ash	1.50	8.3	8.8
N-free extract	15.80	44.4	49.2

TABLE 14. OTHER ORGANIC COMPONENTS PRESENT IN COFFEE PULP

	% on dry wt. basis
Tannins	1.80 – 8.56
Total pectic substances	6.5
Reducing sugars	12.4
Non-reducing sugars	2.0
Caffeine	1.3
Chlorogenic acid	2.6
Total caffeic acid	1.6

silage or as a dried product. Coffee pulp may also be extracted with water or organic solvents to obtain caffeine and other compounds. Some attempts have also been made to extract the protein from coffee pulp as well as the pectic substances; including pectinolytic enzymes. Other approaches include hydrolysis to produce molasses; fermentation to yield alcohol and a variety of extract for soft drinks, jams and similar type of foods. Natural fermentation produces a good organic fertilizer and at the same time evolves biogas.

In India, nearly 75,000 tons of coffee husk is available annually. Approximate composition of husk of coffee arabica and coffee robusta is given in Table 15. The nutrients in coffee husk on dry basis are: digestible crude protein 3.38% and total digestible nutritens 42.2%. In comparison to dry roughages like grain husk, rice and wheat straw, coffee husk contains appreciable amounts of digestible crude protein.

TABLE 15. CHEMICAL COMPOSITION OF COFFEE HULLS

	Coffee hulls	Corn cobs	Cotton seed hulls
Moisture (%)	7.6	8.1	10.4
Dry matter (%)	92.8	91.9	89.6
Crude fat (%)	0.6	0.9	1.10
Nitrogen (%)	0.39	0.39	0.58
Ash (%)	0.50	1.60	2.50
NFE (%)	18.9	48.0	56.7
Ca (mg)	150	765	160
P (mg)	28	274	80

The possibility of using coffee husk as a substitute for chicory has been discussed by Natarajan *et al.* Blends upto 30% husk were acceptable to the taster. But, greater than this were characterised by "hay-like" flavour. Blends with chicory upto 50% were acceptable.

5.2. *Coffe hulls:* The second coffee by-product of importance in terms of amounts available is coffee hulls. Because of the difference in chemical composition (Table 16 & 17) coffee hulls do not offer as many useful possibilities as coffee pulp. As an animal feed the hulls can play a role as a filler only for ruminant ration. The ether extractable substance is too small to be of economic importance. At present coffee hulls are used as a fuel in the drying of coffee beans, etc. It is possible to get animal feed, waxes, fuel, charcoal and acetic acid from the coffee hulls.

5.3. *Coffee oil:* Edible oil can be obtained from dry spent coffee grounds and surplus coffee beans. The oil can be extracted from coffee grounds by solvent extraction. This oil can be used for soap stock without further refining. In Brazil, the surplus beans have been used for production of oil for edible purposes. It may be worthwhile exploring the possibility of recovering oil and then finding ways of utilizing spent material obtained from beverages and soluble coffee.

TABLE 16. COMPARISON OF COMPOSITION OF HUSK OF ARABICA, ROBUSTA AND PARCHMENT (%)

	Arabica	Robusta	Parchment
Ash	5.6	4.4	6.80
Protein	9.2	9.0	2.2
Crude fibre	39.1	38.0	72.4
Water extract	25 – 35	30 – 40	—
PEE	1.4	0.90	—
Alcohol extract	25.1	22.5	1.9
Caffeine	0.3 – 0.6	0.2 – 0.5	—
Roasting loss	20 – 25	20 – 25	—

TABLE 17. FRACTIONATION OF THE CARBOHYDRATE CONTENT OF COFFEE HULLS (%)

Soluble carbohydrates, hexoses	0.45
Structural carbohydrates	
Pentoses	20.30
Hexoses	45.90
Lignin	24.40
Total	91.05
NFE+Crude fibre	96.21

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TABLE 18. COMPOSITION (%) OF MUCILAGE OF COFFEE BERRIES

Total pectin substances	35.8
Total sugars	45.8
Reducing sugars	30.0
Non-reducing sugars	20.0
Cellulose+ash	17.0

5.4. *Tannins and furfural:* Investigations carried out in Latin America suggested that tannins extracted from coffee residues and the organic acids produced by fermentation of coffee husk could be used in tanning.

The comparative potentiality of coffee wastes as a source of furfural is evident. Coffee parchment is superior to coffee husk as potential source of furfural. Coffee parchment yield 13.4% of furfural while coffee husk yields 5.4-6.9% on dry basis.

5.5. *Mucilage:* The use of mucilage and coffee processing waters to produce pectins and pectic enzymes is quite attractive. On the other hand, these by-products have been tested as substrates in microbial processes for the production of pectin. Chemically (Table 18) the mucilage contains water, pectins, sugars and organic acids.

The availability of dried coffee pulp, coffee hulls and mucilage is relatively high and thus of economic importance. Although the price of coffee beans is still the main reason for maintaining and increasing production, the availability of coffee pulp and other by-products in such large quantities certainly warrants efforts to develop profitable uses for these wastes/by-products.

5.6. *Decaffeinated coffee:* In other countries, industries have been developed for the manufacture of decaffeinated coffee. In this case, coffeine is removed from the coffee beans and the subsequent product is roasted and used as a beverage. The scope of such an industry in the country is quite bright.

6. Citrus By-products

Orange, lemon and lime are some of the important plantation crops of India. The citrus industry is expanding rapidly in the country and several processing units have been established. For every ton of fruit processed, 500 to 600 kg. of waste peel remain. Failure to convert this waste to salable products endangers the over all profitability and posses serious problems of disposal. The major economic products obtained from the processing of citrus wastes are carbohydrates, pectin, essential oils, candied peel, acids, vitamins, colours, seed oil and cattle feed.

6.1. *Carbohydrates:* Alcohol soluble carbohydrates can be extracted from citrus peel. On concerntration, this yields molasses which can be fermented to produce alcohol. The citrus molasses is also used in cattle feeds.

6.2. *Pectin:* Pectin can be manufactured from dried citrus peel, especially that of grape fruit. Depending upon the acid treatment, the dried peel has been found to yield about 12% pectin. Extraction and manufacture of pectin from citrus peels have been dealt with by different research workers. The CFTRI, Mysore has developed a process for the manufacture of pectins and essential oils from citrus fruits.

6.3. *Essential oils:* Among the citrus by-products, the essential oils are of major consumer and economic importance. The essential oils are used in cosmetics, perfumes, scented soaps, beverages and confectionery products. The oils are present in oil glands on the outer skin (flavedo) of fruit which on puncturing ejects out oil. The essential oil of the peel varies from 0.11 to 0.58%. The oil consists of terpenes, aldehydes, oxides, alcohols, esters, acids, ketones, α, β-dialkyl acrolins and parafiins. Terpeneless citrus oils are prepared by separating the terpenes from the oxygenated compounds of the oil. The terpeneless oils are valued for their enhanced, flavour value, stability and solubility. Process for the preparation of terpeneless citrus oils has been developed by the CFTRI, Mysore. The low-priced terpene fraction of the citrus oils can be converted into useful and costly products like terpineols, menthol, carvone, etc.

The method of oil recovery in citrus fruits, depends on the process used for juice extraction. With Taglith extractors, the oil is recovered before juice extraction, in an operation in which the whole fruit is rasped under a jet of water. In the FMC extractor, juice and oil extraction take place simultaneously. In another method, the peel after juice extraction is taken and subjected to pressure while the oil is washed away with water sprays. The cold pressed oils are superior in quality. The oil not released by cold press methods may be recovered by steam distillation of the peels. Essential oils can also be obtained from the tender leaves and shoots (Petitgrain oil) and also from the citrus flowers (Neroli oil).

6.4. *Seed oil:* Citrus seeds contain 25-30% of oil which is extremely bitter due to the presence of limonin. However, limonin can be removed and the oil refined by alkali treatment. The refined oil can be used for cooking purposes, while the crude oil can find application in the preparation of soaps and detergents. The principal constituents of the seed oil are glycerol, esters of oleic, palmetic and linoleic acids with small amounts of esters of stearic and linolenic acids. Apart from oil in seed, sterols and limonin-D-ring lactone hydrolase enzyme have been reported.

6.5. *Colour:* Citrus colours (carotenoids, etc.) extracted from citrus peels are highly valued for colouring citrus products, particularly juices and concentrates. The colour can be extracted from whole peel, peeled

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fruits and flavedo yielding 402 to 669 mg/kg of the material. For extractable colours, it is suggested that hexane extraction of wet peel is better than acetone extraction of dried peel.

6.6. *Other uses:* Fresh and brined citrus peel has been used in the production of candied peels which are impregnated with sugar so as to have about 70% TSS.

Several workers have explored the possibility of economically preparing citric acid, riboflavin and vitamin 'C' & 'P' from citrus peels.

Other uses of citrus peel, such as extraction of glucosides, especially hesperidin, methyl chalcone from orange and naringin from grapefruit, have been suggested by several workers.

The excess pulp removed from raw juice is an excellent flavourful material for the manufacture of jams, jellies and bases for soft drinks. Like most commercial fruit pulps, it is stabilized by cooking and sold in barrels with added preservative. At present, this product has only limited demand. Therefore, many processors prefer to recover the soluble solids of the pulp for the manufacture of concentrate.

Ensilage of peels was first attempted in Isreal. The feeding value of such an ensilaged peel was 16% higher than that of whole fruit.

7. Rubber Seeds

The main organic waste available from the natural rubber plantation industry is the rubber seeds. The seeds are collected after dehiscence of fruits. For utilising seeds and for extracting oil, the seeds collected should be heated immediately to prevent further lipase activity.

Rubber seeds consist of 40% shell and 60% kernel. The oil content of the kernel, calculated on the moisture free basis is about 50%. This amount corresponds to 25% of the seeds. The husk contains a solid fat which has a high saponification number and low iodine value. Although rubber seeds contain a cyanogenic glycoside, the oil itself is free from the glycosides and hydrogen cyanide. The composition of rubber seed cake is given in Table 19. The cake is rich in protein and carbohydrates.

TABLE 19. COMPOSITION OF RUBBER SEED CAKE

Constituent	Per cent
Moisture	7.0
Oil	8.0
Protein	30.5
Crude fibre	6.1
Ash	4.9
Carbohydrates	43.5

The average production of rubber seed is estimated to be 1-2 tons per hectare. Total production of rubber seeds will be about 1.8 lakh tons from which 30,000 tons of crude protein would be available in Kerala alone. The availability of rubber seed cake would be 1.5 lakh tons after the oil is extracted. The seed cake has been successfully used for growing cows, cattle and pigs. The rubber seed oil can be used for soap manufacture paint and varnish manufacture, stabilizer for chlorinated hydrocarbons, etc. It is necessary to find out economic uses for cake and oil of rubber seeds. The rubber seed oil and cake should be de-toxified before they are used in food or feeds.

8. Spices

Spices are among the most important plantation crops of India and most of them are exported. Many units have come up in the country for the production and export of spice oils and oleoresins. India exported 4 tons of pepper oil and 110 tons of pepper oleoresin during 1976–77 and earned rupees 140 lakhs in foreign exchange.

There was not much of a problem in the utilisation of waste/by-product in the spice industry. But after the establishment of spice oil and oleoresin industries, the problem has been on the increase. The problem can be illustrated by the following example. By producing 4 tons of pepper oil, we get about 200 tons of spent material for disposal. By producing 110 tons of pepper oleoresin about 1000 tons of spent material would be available. Like pepper, most of the spices yield either essential oil or oleoresin or both. The yields of essential oil and oleoresin from most of the spices will not be more than 5% and 15% respectively.

What are the possible uses for these spent materials? At present, they are either used as manure or are burnt. One has to explore the possibility of utilising the spent materials in better ways. The possible uses may be: (1) as cattle feeds, and (2) as source materials for the extraction of colours, fibre, oil, starch and chemicals.

A recovery of 0.15% of ginger peel oil could be obtained by distillation of ginger peels which will be obtained while converting green ginger into dry ginger. It is estimated that a gross income of rupees 15 lakhs will be obtained by the profitable utilization of this waste material. There is a need for developing this industry in Kerala. Similarly, 8-10% of the weight of turmeric is the polishing wastage obtained during full polishing of turmeric rhizomes. The cardamom husk and spent seeds could be used in *agarbathi* manufacture. There is scope for extracting colours from ripe berries of pepper and paprika. The dried outer leaves/skins of onion are the good source of quercetin. A simple rapid

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method for the extraction and purification of this flavouring component has been reported recently.

The tender leaves and twigs of cinnamon plants can be distilled to get 1.8 to 3.75% of essential oil which is very rich in eugenol (85-90%). Eugenol finds use in pharmaceutical, perfumery and flavouring industries.

9. Tea

India is one of the largest tea producing nations. Nearly 550 million kg. of tea is produced every year in India. Tea waste in the form of fluffs, stalks, dust and sweepings become available during the course of production, storage and handling at tea gardens, factories, railway wagons, ware houses, etc. It is estimated that about 15 million kg. of tea waste is available (in India) in a year, and half of it comes from Assam alone. This may amount to almost 3% of the total tea production in the country. Instant tea plants are coming up in India and elsewhere also. It would appear that the potential for instant tea is expanding rapidly. The waste/spent material obtained from the instant tea/soluble tea/green tea units is enormous and waste disposal is a serious problem. Therefore, research should be focussed on the utilization of spent leaves of tea and wastes obtained from tea industries. The by-products that could be obtained from tea are given in Table 20.

9.1. *Extraction of caffeine:* At present a large amount of tea waste of the order of 8,000 to 10,000 of tons is burnt. But this tea waste is nothing but a part of good tea; it has all the chemicals which are present in good tea. The tea waste or refuse tea accounts for 3 to 4% of the black tea production. The component of tea waste which is best known is caffeine. Tea waste contains 1.5 to 3.5% caffeine and the commonly used method of extraction of this alkaloid is by the use of organic solvents. Here the main problem appears to be efficient recovery of the solvent (usually trichloroethylene). Apart from its pharmacological properties, caffeine is also an essential ingredient of carbonated beverages, notably cola types. R.R.L., Jorhat, has developed a process for the production of caffeine from tea waste. A plant with a capacity of 20 tons of caffeine from tea waste per year has been set up in Assam.

TABLE 20. BY-PRODUCTS OF TEA

Source	Product
Leaf	Black tea Green tea
Waste tea	Instant tea Caffeine Food colours Culture medium Tea-cider Tannin
Bark	Tannin
Seed	Oil Saponins Residue for animal feed
Tea beverage	Clinical uses e.g.: Atherosclerosis Dental caries Radiation disease Dysentry

There are certain problems in waste utilisation. The Indian Tea Association has banned the sale of tea waste to prevent its use as an adulterant of good tea. Collection and transport of tea waste is not easy and economical. If the tea waste is utilized, about 225 tons of caffeine can be produced which will stop not only imports but also open export potentialities as well. One of the most auxiliary industries based on caffeine would be the production of theophylline which is an important diuretic used by the pharmaceutical industry. The other chemicals obtained from caffeine are aminophylline (antiasthematic), bramamine (antimotion sickness drug), etc.

In the caffeine extraction plants, exhausted tea waste obtained after extraction of caffeine from tea waste is available upto 4 million kg. per day. This is free from the solvents used during extraction of caffeine. Contents of tannins in the original tea waste (20-25%) remains practically unchanged in the exhausted tea waste. In Japan, this waste is used as cattle feed. It can be used, as manure, for the manufacture of activated charcoal and sound proof bricks. Utilisation of the tea waste makes India more viable and competitive.

9.2. *Production of colouring matter and other chemicals:* Another use for waste tea is the extraction of colouring matter for the food industry. Green, yellow and brown pigments, corresponding to the chlorophyll and polyphenolic material, are being extracted and used. In addition, waste tea also contains about 5% pectin and 20% cellulose and these should be exploited.

Another possible use of waste tea is as a culture medium for various fungi which contain a potent tannase enzyme. Using a special mixture of organisms, extracts of tea with added sugar may be fermented to palatable tea cider, containing about 1% of alcohol. Instant tea has also been produced from tea waste and this may be worthy of consideration as most profitable use for waste tea. The polyphenols (gallocatechins and catechin gallates) of tea can be used as antioxidants in food products.

Agricultural wastes which can produce pentosans on acid hydrolysis can be further converted into furfural. Tea waste can be used for the production of furfural.

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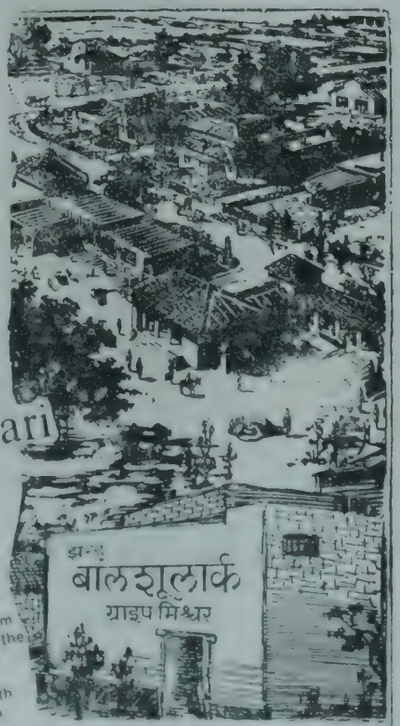

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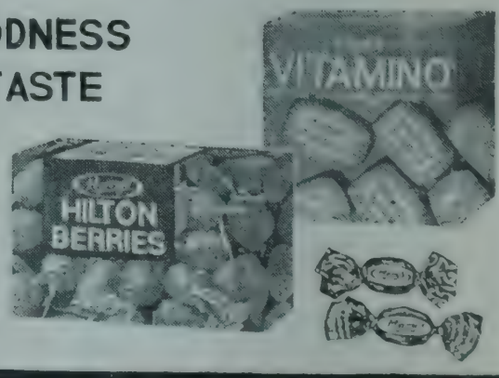

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Triacontanol, the long chain fatty alcohol ($C_{30}H_{62}O$) has now been recognised as a plant growth promotor. Instant tea waste contains the maximum amount of triacontanol followed by black tea and green tea. Isolation and production of triacontanol from instant tea waste will considerably help in reducing the cost of instant tea processing.

9.3. *Tea seed:* Tea seed contains valuable substances like oil and saponin. The content of oil is about 20% and is similar to olive oil in chemical composition. It has been found to contain 72% oleic acid and 15% linolenic acid, both of which can, if required, be hydrogenated to stearic acid. This stearic acid could be made use of by the tyre industry. Some of the important properties of the tea seed oil are: Iodine value 88.9; Saponification value 187.4; and free fatty acid content 5.34%.

It is estimated that it will be possible to obtain 100 kg. of tea seeds per hectare, if small holders are encouraged to concentrate exclusively on the production of tea seeds. Seventy percent of the oil in the kernel of the seed and thirty percent in the shell, apart from being a superior cooking oil, has a variety of other uses.

The tea seed cake remaining after oil extraction contains another valuable product, saponin in appreciable quantity (10 to 15%). Saponins are used in the beer industry for the production of a long-lasting foam. Saponins are practically non-toxic to man upon oral ingestion, but act as powerful haemolytics when injected into blood stream, dissolving the red blood corpuscles even at extreme dilutions. Saponins are also used in the formation of oil-in-water emulsions, preparation of hair shampoos, antiseptics and cough drops. They are also invaluable in the sensitization of photographic emulsions and this may be the most profitable line to pursue. Chemically, saponins consists of two moieties,one of which is the sapogenin and the other a mixture of sugars.

9.4. *Tea root:* Saponin also occurs in tea roots which contain about 5% of this compound and this finding merits consideration when extensive uprooting programmes are undertaken.

9.5. *Other uses:* The residue after extraction of oil and saponin form about 60% of the original seed material and contains about 2% N, 0.5% P and 2% K. Its high content of protein (12.6%) indicates that it would be useful as a cattle feed, especially in terms of all the essential amino acids present therein.

The tea leaves/wastes are found to be a source of vitamin 'P' and the tea beverage helps in the prevention of atherosclerosis. Tea drinking helps in preventing dental caries and dysentry.

10. Tapioca (Cassava)

Cassava (*Manihot esculenta* Crantz) is an important plantation crop of Kerala, parts of Tamil Nadu, Andhra, Pradesh and Karnataka States. Cassava is of considerable importance in many tropical countries as a staple food for human consumption as well as for cattle feed. In addition to food uses, cassava is also used in industrial processes for the production of starch or when hydrolysed enzymatically for the production of glucose. Cassava has also been used for the production of beer. Cassava is a root crop and normal yields are about 5 kg. per plant. The leaves are also eaten (after cooking) and are noteworthy for their high protein content. The roots deteriorate within a few days after harvest.

10.1. *Cassava rind:* Cassava root (tuber) consists principally of two sections the bark (peel or rind) and the central cylinder or pulp. The central cylinder consists of the secondary xylem where the starch is stored. Cassava rind is a waste material in the sago and starch industries. The rind is also thrown out as waste material when the tubers are used for consumption purpose. The rind varies from 10-15% in the tubers. The rind or peel is rich in starch (10-12%), cellulose and other nitrogenous materials. The total production of cassava in India is about 6.35 million metric tons and about 0.6 million metric tonnes of rind is expected from the tubers. Analytical values on the peel are scanty and this portion is now used increasingly for live stock feeding. The percentage composition of the peel and pulp of cassava is given in Table 21. According to the studies by the C.T.C.R.I., Trivandrum, cassava rind can be utilised as a potential source for single cell production (protein) and also for extra cellular production of amylases.

10.2. *Cassava seed oil:* Some of the varieties of cassava flower produce seeds which resemble castor

TABLE 21. PERCENTAGE COMPOSITION OF THE PEEL AND PULP OF CASSAVA

	Dry matter	Ether extract	Ash	Crude protein
Peel	23.47	2.46	5.99	6.97
Pulp	26.37	0.59	2.44	2.21

TABLE 22. PHYSICO-CHEMICAL PROPERTIES OF CASSAVA SEED OIL

Colour = Very light yellow
Odour = Very faint
Refractive index at 29°C = 1.471538
Specific gravity = 0.8637
HCN content = Nil
Iodine value = 120
Saponification value = 145
Acid value = 4.0
Peroxide value = Nil

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WRITE To

The Executive Director,
Protein Foods and Nutrition Development Association of India
Mahalaxmi Chambers, 22 Bhulabhai Desai Road
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seeds. The fruits are tricarpellary. The seeds are presently not used for any purpose. Most of non-branching varieties of cassava are either shy flowering or non-flowering; whereas the branching varieties flower profusely mainly during Oct.-Dec; 6-7 months after planting. Around 3 kg. of seeds are obtained from one plant. The seeds are good source of proteins and contain about 40% of lipids which can be extracted by usual methods. The lipids have been analysed to contain over 96% of triglycerides and very less free fatty acids. They contain as high as 62% of unsaturated fats and hence offer a good source of the same. The physicochemical properties of cassava seed oil is given in Table 22. According to reports from the CTCRI, Trivandrum, the oil was found to be highly unsaturated with $C_{18:2}$ component (linoleic) predominating. Samples stored for 2 months did not show any appreciable variation in the properties.

10.3. *Other uses:* The chief use of cassava is as a boiled vegetable. It can be processed into macaroni and a rice like food. In the form of dried chips, cassava root is an important animal feed in the international market and is used extensively in Europe. Cassava root is a poor food and its protein content is extremely low. All parts of the plant contain glucosides of hydrocyanic acid (prussic acid).

Cassava has a bright future as an industrial starch crop, as food and feed crop, and as a substrate for the production of protein by yeast and fungal fermentations.

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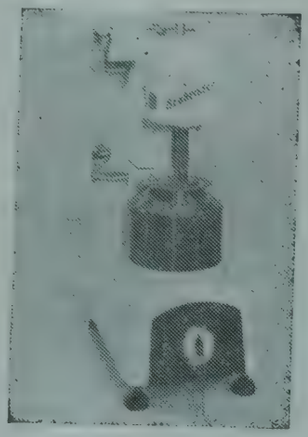

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The Oilseeds and Oil Processing Industries: By-products, Wastes and Effluents

K. T. Achaya

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The processing of oilseeds in bullock-driven ghanis in India is an industry as old as its recorded history. Sesame seeds and rape/mustard are mentioned in the Vedas, and no doubt the processing of coconut to edible oil is of great antiquity in the South. By-product cakes from all these oilseeds were excellent protein-rich cattle-feeds, and that from castor seed (a subsequent development) a first-class manure. Since all could be used locally, there were hardly any disposal problems. The coconut did give rise to coir and to coconut shells, but the use of the former for making ropes and mats and the latter for small household utensils or for burning as fuel led to systems in which all by-products were used.

Today the emphasis is on value added, with a tendency to deprecate the use of woody or starchy materials for burning in boilers or ovens. The escalating costs of furnace oil could lead to a return to older thinking, but other uses that yield value still need to be considered. Some of these are reviewed in this paper, and for convenience this is done commodity-wise.

1. Oilseed Processing

1.1. *Groundnut*

Our major oilseed, groundnut, yields no less than 30 percent its weight of shells or hulls, which largely continue to be used as fuel in boilers or for field drying operations. An improvement is represented by the creation of logs from the hulls using wax as a binder followed by shaping and cutting, which makes transport easier. A great deal of work has been done on the conversion of groundnut hulls after grinding into particle boards for use as building and packing materials. It is usual to add about half the weight of wood dust to the composition, and generally 5-10 percent adhesives like phenolic resins, preservatives and fire retardants are also generally employed before applying pressure and/or steam, followed by curing. The boards are attractive in appearance and sufficiently strong for use as room partitions and even as hardboards. If extreme pressure is employed, which of course involves more expensive equipment, the use of adhesives can be greatly minimised.

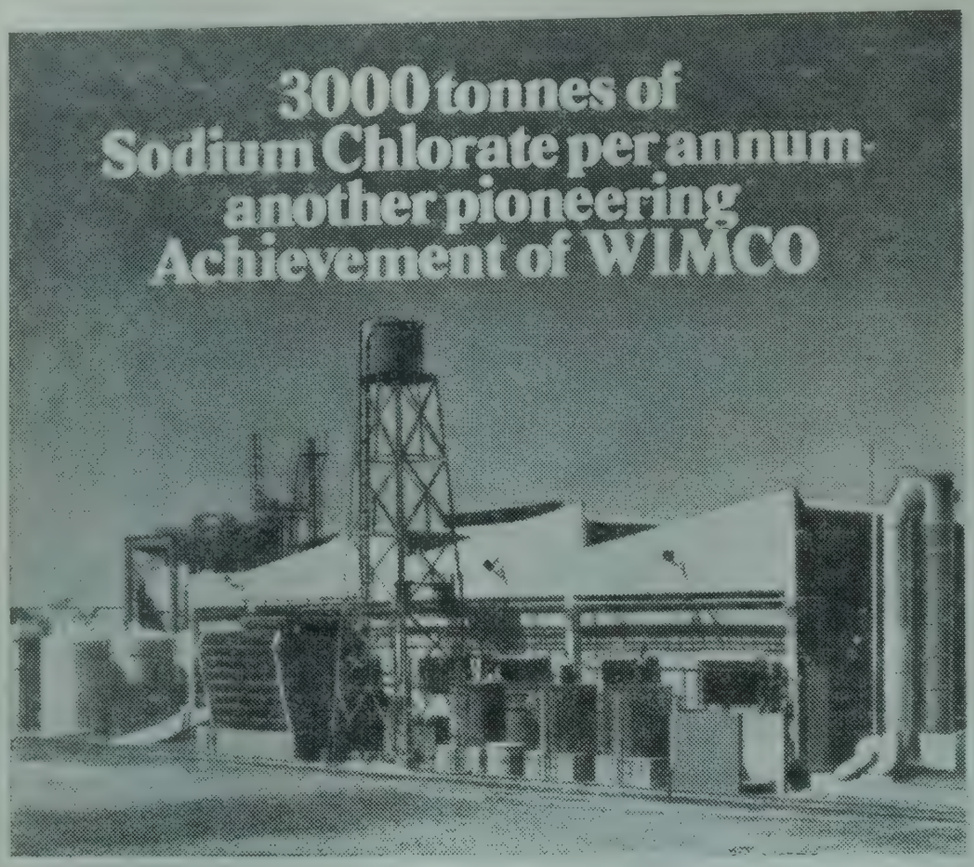
A lesser-known use for groundnut hulls is as animal feeds after pretreatment with alkali, which has the effect of increasing digestibility remarkably from about 20 percent to over 50 percent. Another use in the modern poultry industry is as a bedding material in the pens, where bird droppings further enhance the digestibility. The preparation from groundnut hulls of activated carbons is by treatment with activators like zinc chloride, phosphoric acid or calcium hydroxide, followed by burning of charcoal out of contact with air and further carbonisation at a high temperature to create hot spots and channels on the catelyst surface. These carbons are characterised by excellent colour and odour retention properties that lead to their use in the pharmaceutical, vegetable oil, water treatment and gas absorption industries.

Generally the red skins of groundnuts are not removed before processing for oil. If the cake is intended to be used as an edible flour for human use, the nuts are toasted and the red skins detached. This is a highly nutritious material, with 13 percent protein, which could go into animal feeds. Another unusual use is as a chelating agent for removal of heavy metal ions from water, for which the skins are treated with formaldehyde using sulphuric acid as catalyst, when the tannins get condensed.

1.2. *Cottonseed*

This oilseed, a comparatively recent entrant on the Indian scene, yields two derived products in course of processing. First are the linters, the fluff that still adheres to the seed after the cotton has been ginned, and which are removed from it in delinters in one or two successive cuts, the quantities of which can be adjusted. It is usual in India to take a rather small first cut since the second cut has a better demand and price, or even to do a single, or mill-run, delinting. The first-cut linters have long fibre lengths and go into paper making, felting and straw board manufacture where the length confers good wet strength and texture. The second-cut linters are shorter and go entirely into the preparation of chemical derivatives like cellulose acetate, cellulose nitrate and carboxymethyl cellulose where quick dissolution in alkalies is called for. Mill-run linters enter both types of uses.

The next product arising from cottonseed processing is the black hulls. These are removed by disc or bar hulling the delinted seed, giving as the other product the inner kernels that are used for oil extraction. Hulls are a very valuable roughage in cattlefeed since they consist of alpha cellulose, pentosans and lignin, and both in India and elsewhere this is their main use. After



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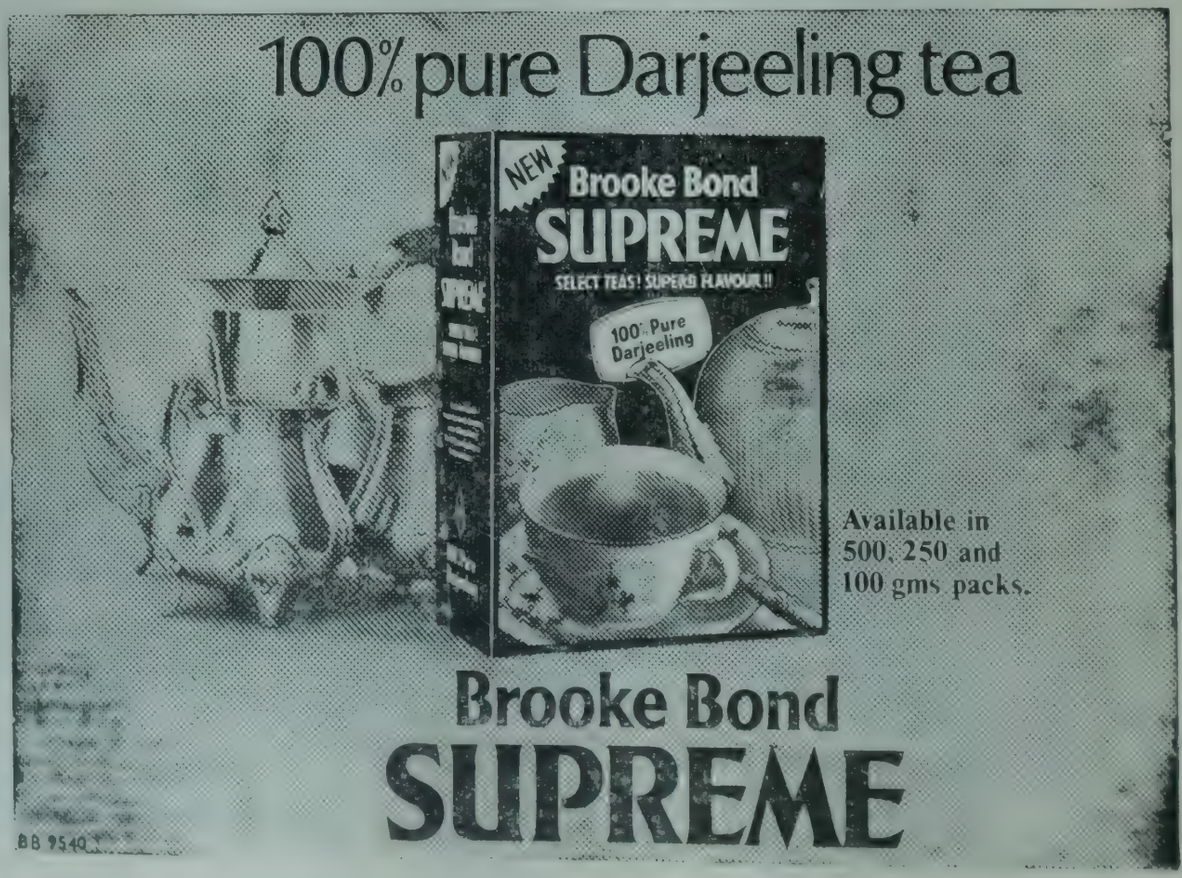

the kernels have been freed of oil by either screw pressing or solvent extraction, the hulls are added back to the cake and remixed. On the Indian market, undecorticated cake with 20-24 percent protein and 20-24 percent crude fibre is the standard trade commodity, and adding back to the cake 30-35 percent of hulls (with a crude fibre content of about 50 percent) will give such a product.

With such a good return for hulls as a component of cattlefeed, there is little economic incentive for other outlets. Their bulky nature makes for excellent use as soil conditioners, the lignin and pentosan components helping to build up soil humus. Preparation of hardboards or of active carbons as described for groundnut shells has been demonstrated for cottonseed hulls also. Digestion with hot alkali followed by bleaching yields alpha cellulose for use in making viscose rayon. The pentosans can be hydrolysed and then heated to give furfural, a component of paints and plastics, in a theoretical yield of about 20 percent, using glass units for redistillation of the primary distillate.

1.3. *Coconut*

Coconut yields somewhat unusual by-products since the nut is rather densely buried in a fibrous cocoon. Prying apart this husk yields coir, a coarse mass which is retted and sorted to fibres of various thickness and lengths that are further woven or fashioned into ropes, bags, mats and floor coverings. A fair proportion is burnt as fuel. A new use of coir is as a rubber-coated material that is fashioned into springy mattresses and pillows which allow circulation of air, and are competing with flexible urethane foams in these uses.

A by-product of husk processing to coir is coir dust, a product rich in cellulose and lignin which can absorb 65 percent of its weight of moisture. It contains 70 percent of pith, and both short and long coir fibres, and is a serious health and fire hazard when it piles up near the processing plants. Coir dust has been used as a soil conditioner since it can absorb water, and as a land fill for reclamation. Use in resin-hardened particle boards and insulation slabs is in practice, while utilisation of rubberized coir powder for floor and ceiling compositions is being explored. Activated carbon manufacture has been suggested.

Coconut shells, the woody globe that holds the precious meat and water, have had the traditional uses earlier described. One of the outlets that seems obvious but does not appear to be fully pursued is conversion into charcoal by burning with limited access to air, in such a way that the volatile by-products are condensed and the tar drained and collected. Charcoal production from wood in this way is a common industry, though the by-products are generally not recovered. Coconut shell is also an exceptionally useful material for production of active carbons after chemical activation, as described earlier. The products are characterised by exceptional gas absorption ability which makes them specially applicable in vapour recovery, gas masks and canisters, and the like.

1.4. *Castor*

The normal practice in India is to crush castor seed as a whole to yield the oil on the one hand, and on the other castor cake admixed with hulls, which may be deemed a by-product. This is an outstanding fertilizer for several reasons: slow release of nitrogen and phosphorus into the soil, a fair content of potassium, and soil-conditioning qualities. The attempt everywhere is to convert inedible oil cakes such as castor to edible materials, and a plea is made here for continued use of castor cake as a natural organic fertilizer for which it is in many ways unique. The new trend away from synthetic fertilizers based on dwindling raw materials would go in support of a manure derived from a renewable resource like the castor.

2. Vegetable Oil Processing

Having considered the by-products derived from oilseed processing, those that arise from the industrial processing of vegetable oils themselves may now be given attention. The refining, bleaching, hydrogenation and deodorisation of ils lead to by-products that are common in nature, and accordingly the classification will be based not on the exact oil processed, but on the nature of the by-product.

2.1. *Lecithins*

This rather old term for phospholipids is still used in the trade. Phospholipids are soluble in vegetable oil, but when the oil is brought into contact with water, they get hydrated and are thrown out of solution as a gummy material. This can happen during conscious hydration or degumming of an oil like the soyabean prior to alkali refining, or if solvent-extracted oils are held in tanks, when a thick sludge of hydrated material slowly precipitates. Soyabean lectithin in various forms is a valuable food emulsifier, and is routinely recovered and beneficiated. Cottonseed oil on hydration yields dark gums that are sometimes recovered so as to reduce subsequent oil-refining losses, but the product is never refined and is simply added back to cottonseed cake. Its use for manufacture of printing inks and surface coatings has been demonstrated in India. Oil-tank sludges are a convenient source of groundnut lecithins, which can replace soya lecithins even in many edible uses.

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2.2. *Soapstocks*

Removal of the free fatty acids that have developed in vegetable fats by hydrolysis is effected by treatment with alkali lye of various strengths to give a solid or liquid soapstock. If the fat is of light colour, such as groundnut oil or vanaspathi, so is the soapstock, which can then be directly employed for conversion into washing or even toilet soap as part of the charge. But refining of say cottonseed oil yields a black soapstock which cannot be so used. Repeated graining out of the soap matter with salt will improve the colour but at great loss of soap. There is a cottage industry based on such poor-grade soapstocks which are filled with earth as an abrasive, set, and cut to give cheap black cakes sold unwrapped on the pavements. The industrial solution to such dark soapstocks is to acidify and distil under vacuum the valuable fatty acids present for other use. Distillation being an expensive operation, there are limitations to this outlet, since soapstock has to be transported from scattered refining units to a central distillation plant. Moreover even distillation of cottonseed soapstock does not give a material totally free of colour, or more important, of odour. Simple straight vacuum distillation in small decentralised units might be the best approach to this waste of valuable fatty material, which at present is mostly burnt in boilers. Cattle can tolerate and utilise alkaline soap, and also detoxify the gossypol present, so use of cottonseed soapstock as the fat component in cattlefeed rations represents another outlet.

2.3. *Deodoriser distillates*

The last stage of refining both edible oils and vanaspathi is to subject them to the action of steam under vacuum at high temperature, which strips them of odoriferous and volatile components and yields a bland oil. The distillates that accumulate are a mixture of fatty acids with hydrocarbons, ketones, aldehydes, sterols, tocopherols and so on. Attempts have been made to recover sterols and tocopherols from deodoriser distillates but without much commercial success. Of course, the quantities involved are not large, being about 0.1-0.2 percent of the oil per hour of deodorisation time.

2.4. *Spent catalyst and used earth residues*

In the USA, where recovery has generally been considered uneconomic, at least till recent times, the usual method of disposal of these solid wastes was for the industry to transport them in trucks, after covering with earth to prevent fire risks, to land-fill operations on the outskirts of most cities, dump them and beat them down. Since nickel metal is scarce in India, it is now customary to re-extract it from spent nickel catalyst derived from the hydrogenation operation, which carries 4-14 percent of the metal embeded in fat. The usual procedure is to extract the fat with a suitable non-polar solvent, after which nickel is leached out with a suitable acid. Generally iron must be removed in a specific operation, such as by precipitation with phosphoric acid. A dozen firms appear to be recovering nickel in this fashion in India.

The filter presses in oil refining plants on cleaning yield a mud carrying about a third its weight of oil. This may simply be boiled with caustic to yield cheap soaps that are ready-filled with abrasive earth! To recover oil, the mud can either be treated under steam pressure with solutions of alkali or synthetic surface-active agents which displace and release the oil, or extracted with solvents in autoclaves or percolation-type batch extractors. The oil thus obtained is rarely of high quality. The earth that remains can in theory be re-activated by acid and heat treatment, but is never the equal of the fresh material.

3. A Total View

3.1. *Priorities*

In terms of production volume of oilseed processing by-products, groundnut hulls, coconut coir dust and coconut shells would rank high as targets for value-added utilisation. Groundnut hulls make up about 18 lakh tonnes annually, coconut coir dust 1.6 lakh tonnes and coconut shells something like 0.2 lakh tonnes. Vegetable oil processing by-products are of course much smaller, and perhaps the largest is cottonseed soapstock, generated to the extent of some 35,000 tonnes annually. These would therefore represent priority areas of waste utilisation in this industry.

3.2. *Environmental pollution*

Consciousness is just arising in India regarding the pollution of the earth, water and sky with residues that could linger. The oilseed industries have been rather complacent in this regard because oil-based products are in the main biodegradable. However, as the volume of production increases, the load factor itself may constitute a hazard.

Some observations drawn from the developing countries regarding wastes may be helpful as a pointer. The USA has both an Environmental Protection Agency which has strict standard for example for the percentage of solvent in the atmosphere in a solvent extraction plant, since a certain level constitutes both a fire and an inhalation hazard. The National Fire Protection Agency, located in Boston, also has codes of safety in this regard. Effluents, if generated within city limits, can be run into the municipal sewage systems, but the processing unit must pay for its treatment according to the level of solids, the biological oxidation demand, the nature of the constituents as determined by analysis, and so on.

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There are several procedures followed for the treatment of water effluents containing oil. Gravity separation is one of them, and the American Petroleum Institute has designed units for the purpose. Another technique is to add a coagulator and earth, followed by pressure filtration. A third approach employs compressed air to cause the diffused oil globules to float and coalesce, the unit being termed a flotator-clarifier. A slower system utilises two activated slugde lagoons in series with a ten-day residence time in each, before reuse or discharge of the water.

Dairy Effluents and Discharges and Equipments for Their Disposal

G. R. Anap and S. P. Agrawala

Dairy Engineering Division, National Dairy Research Institute, Karnal, Haryana

In India 3.75 million tonnes of milk is processed by organised dairies. The processing of one litre of milk yields 2-8 litres of wastewater depending upon the product made and quantity of milk processed. The wastewater from dairies include the wastes collected from various processing sections of the plant. The dairy effluent is very rich in organic matter content and has very high biological oxygen demand (BOD). Therefore it cannot be discharged into the rivers or streams without causing pollution. The ISI tolerance limits for discharging the dairy wastes into rivers, public sewer or to use it for irrigation purpose are 30 mg/1, 500 mg/1, and 500 mg/1 respectively. Therefore before discharging this wastewater to rivers or city drain or to utilize this for irrigation purpose, it should be treated to meet the requirements of the Indian standards.

1. Wastewater Sources

The wastewater from the dairy plant includes the wastes collected from various processing sections of the plant viz. market milk, cheese, ice-cream and indigenous milk products section. These wastes arise out of rinsing and washing of bottles, cans, milk lines, milk tanks, milk pumps, *ghee* kettles, *ghee* plant, *khoa* pan, *channa* and *Pedha* processing units.

1.1. *Market milk section:* Wastes from this section include milk drippings, rinses and washings of milk receiving dock, milk cans, milk bottles, cream separator, H.T.S.T. pasteurizer. This also includes spilled milk, cream, separated milk and floor washings. Wastes from bottle washer and can washer include soda and other detergents to the plant wastes.

1.2. *Condensed and dried milk section:* Wastes from condensed and dried milk section includes spilled condensed milk and dried milk powder, washings of the evaporator, vacuum pan, roller and spray drier and floor washings.

1.3. *Butter and cheese section:* In cheese manufacturing process the yield of cheese varies from 10 to 16 per cent depending upon the variety of cheese manufactured. But the major lot of the milk, nearly 84 to 90 per cent in the form of whey is dumped into the wastewater line of the plant. Butter milk and washings of butter churn, cheese equipment and floor washings also contribute to the wastes from this section.

1.4. *Ice-cream section:* Spilled products like cream, flavoured milk, cream powder, ice-cream mix and washings of equipments, viz. ice-cream freezer, filling unit and homogenizer are the major sources of wastes from this section.

1.5. *Indigenous milk products section:* Indigenous products section wastes include spilled milk from *paneer* vat and *khoa* pan, *ghee* residue, whey from *paneer*, *channa*, and *shrikhand* manufacturing processes. Floor washings, washings and rinses of *khoa* pan, *paneer* vat, *channa* making equipment, *shrikhand* plant and *ghee* plant also add to the volume of wastewater.

2. Flow and Nature of Wastewater

Wastes from dairy plant often show wide variations in flow and quality of waste. Mohanrao and Subrahmanyam (1972) reported that the rate of discharge from a plant varies considerably from hour to hour, an acute peak about five times that of average appeared in the afternoon (2-4 p.m.) and a minor peak twice the average in the early morning hours (3-5 a.m.). They observed that the BOD requirement varied from 600-1000 mg/1 for simple bottling plant wastes to 1850 mg/1 for product plant wastes.

The nature and composition of the dairy plant waste depends upon the products made and quantity of milk processed. The biological or biochemical oxygen demand (BOD) of the waste varies with the composition of different constituents. The major constituents of milk contributing to BOD are lactose, fat and milk proteins. BOD_5 values of these constituents are 0.65, 0.89 and 1.03 kg per kg of the component respectively.

Table 1 and 2 show the characteristics of the combined

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TABLE 1. CHARACTERISTICS OF THE COMBINED WASTES FROM A SMALL SIZE DAIRY. VALUE OF MILK PROCEESSED = 12 800 L/D WASTE VOLUME = 3.6 L/L OF MILK. ALL VALUES EXCEPT PH ARE EXPRESSED IN MG/L

	Combined waste
pH	8.1
Total solids	2.730
Volatile solids	2.205
suspended solids	1.810
Volatile suspended solids	1.660
Alkalinity as $CaCO_3$	220
Volatile acids as (CH_3 COOH)	20
COD	4 510
BOD	3 070
COD : BOD	1.47
BOD rate constant (K/day)	0.19
Total nitrogen (N)	1080
Total phosphours as (P)	110
Sulphates (SO_4)	45
Fat	1390

Source: Rengasamy G. (1969).

TABLE 2. CHARACTERISTICS OF COMPOSITE WASTES FROM A LARGE DAIRY. A PRODUCT ORIENTED DAIRY PROCESSING ABOUT 360 000 L/D OF MILK. FLOW: 6-8 LITRES OF WASTE PER LITRE OF MILK PROCESSED

	Combined waste
Temperature	38°C
pH	10.1
Colour	Mi ky white
Alkaiinity as $CaCO_3$ to pH 4.3	340
to pH 8.3	170
Total solids	790
Volatile solids	320
Fixed solids	470
Suspended solids	78
Chlorides	35
BOD	950

Source: Rengasamy G. (1969).

wastes from a small size dairy and large size dairy plants. The total solids present in the effluent were 2730 and 950 mg/1 in small size and large dairy plant respectively. Similarly the BOD requirement of small size dairy plant was much higher as compared to large size dairy plant. This variation in BOD requirements in different dairy plant wastes needs to be evaluated on a plant to plant basis in order to get useful data for designing or selecting an efficient waste disposal method for the plant. However, overall BOD_5 values and contribution of various components of waste to these values are listed in Table 3, these data could be used for rough estimations and calculations of total waste load.

TABLE 3. BOD_5 VALUES AND CONTRIBUTION OF MILK COMPONENTS TO BOD_5

Product	BOD_5 (mg/1)	% contribution to BOD_5 by milk fat	milk protein	lactose	lactic acid
Skim milk	67.000	6.3	49.3	44.5	—
Whole milk	104.000	31.5	36.4	32.2	—
Butter milk	68.000	4.2	48.2	46.7	0.98
Voghurt	91.000	27.8	37.6	27.1	7.2
Evaporated milk	208.000	34.6	35.0	30.6	—
Ice cream	292.000	30.7	15.9	15.2	—
Whey	34.000	5.9	20.6	70.8	2.8

Source: Second National Symposium on Food Processing Wastes, 1971, USA.

This biological oxygen demand of the dairy wastewater depends also upon the nature of unit operations involved in the process plant. Higher BOD values have been reported for cheese making, roller drying. evaporating and drying milk as compared to other unit operations like receiving, cooling and storage of milk. This may be because of total solids present in cheese, evaporated milk and dried milk is more than the total solids present in milk at receiving dock. Table 4 gives the reported BOD values for different dairy unit operations.

Detergents and sanitizers also contribute significantly to the BOD of dairy wastewater. Some time they also cause toxicity and become responsible for poor performance of dairy waste treatment plant. Table 5 gives BOD_5 values of selected detergents, sanitizers and lubricants commonly used in dairy plants.

TABLE 4. REPORTED BOD LOSSES FOR VARIOUS DAIRY PLANT UNIT OPERATIONS

Operations	Loss kg. BOD/ 1000 kg milk processed
Receiving and cooling milk	0.20 – 0.65
Storage of milk (tanks)	0.05 – 0.18
Cream separating	0.13 – 0.40
Milk pasteurization storage and bottling	0.80 – 1.08
Spray drying (whole milk)	0.10 – 0.20
Roller drying	0.51 – 1.80
Evaporating and drying (skim milk)	0.74 – 1.02
Butter churning and washing	0.20 – 0.92
Cheese making	0.89
Condensed milk	1.40
Evaporated milk and canning	0.75
Washing tankers	0.25

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TABLE 5. BOD_5 VALUES OF SELECTED CHEMICALS USED AS DETERGENTS, SANITIZERS AND LUBRICANTS IN DAIRY PLANTS

Material	Kg BOD per kg. product
Acetic acid	0.65
70% hydroxyacetic acid	0.07
Napco, IIII-Sulfonated coconut oil	0.96
Napco 1665, Soluble fatty acid ester	0.12
Pine oil	1.08
Tallow	1.52
Ethylene glycol	0.70
Zalon-fatty amide	0.20
Linear alkylarysulfonate	0.65

Source: Second National Symposium on Food Processing Wastes, 1971, U.S.A.

3. Wastewater Disposal and Equipments

Discharges from milk plant processes normally contribute substantial amount of fat, milk proteins, lactose, minerals, detergents and sanitizers. The lactose in the absence of sufficient oxygen is converted into lactic acid, the precipitated casein putrifies and produces strong and offensive odours. However this rich organic matter can be readily degraded like municipal wastes in trickling filter, biological disk, aerated lagoon, oxidation ditches, ponds, etc.

3.1. *Trickling filter:* This is a conventional process used to treat large kinds of wastes in which either slow rate or high rate biofilters are used for treating industrial wastes. The choice between slow rate and high rate biofilter depends upon influent effluent quality, hydraulic retention time and the cost of the treatment. Slow rate biofilters have broken brick of stone pieces as the media for bacterial growth in the filter bed where as in high rate biofilters, high density PVC open structures of regular geometry with 90 per cent porosity are used as filter bed for microbial growth. The higher voids ratio prevents the blockage of excess microbial growth and also ensures adequate air supply for bacterial growth.

Higher rate biofilters are generally plug flow reactors and the BOD removal follows the first order kinetics.

$$\frac{Le}{Li} = e^{-K_1 t}$$

Le=effluent BOD, mg/l,
Li=influent BOD, mg/l,
K_1=first order rate constant for BOD removal, d^{-1}
t=hydraulic retention time, d.

3.2. *Activated sludge:* Activated sludges and its modifications like contact stabilization, extended aeration etc. are quite popular in treating dairy effluents. This process requires less construction costs. Normally a loading of 0.3 to 0.5 kg BOD/kg MLSS/day may be adopted, but this process is sensitive to shock loadings.

3.3. *Aerated lagoon:* This is a simple 3 to 3.5 m deep earthen pond in which mechanical aerators (Fans) are installed to aerate the wastewater. The laboratory feasibility studies to use this system for dairy plants were conducted at CPHERI (present NEERI), Nagpur. The overall system rate constant 'K' for 90 per cent BOD removal was calculated to be 0.274 and hydraulic retention time was 3.7 days. These results show the wide applicability to the aerated lagoon ditches in dairy industry.

3.4. *Oxidation ditch:* Oxidation ditch is an oval shaped closed circuit. The highly concentrate influent to the ditch is intensely aerated to incorporate more and more oxygen per unit time to the wastewater at the entering channel to the ditch. This system is much less expensive than conventional activated sludge in capital cost. An organic loading of 0.12 to 0.15 kg/BOD/kg MLSS/day may be adopted in design.

3.5. *Stabilization pond:* Waste stabilization pond is also quite popular method in dairy waste treatment. This is because of its low cost of construction and easy operation than other methods. The pond has very large surface area and shallow depth and is enclosed by earthen embankments. This is a mixed flow reactor and BOD removal follows first order kinetics. The

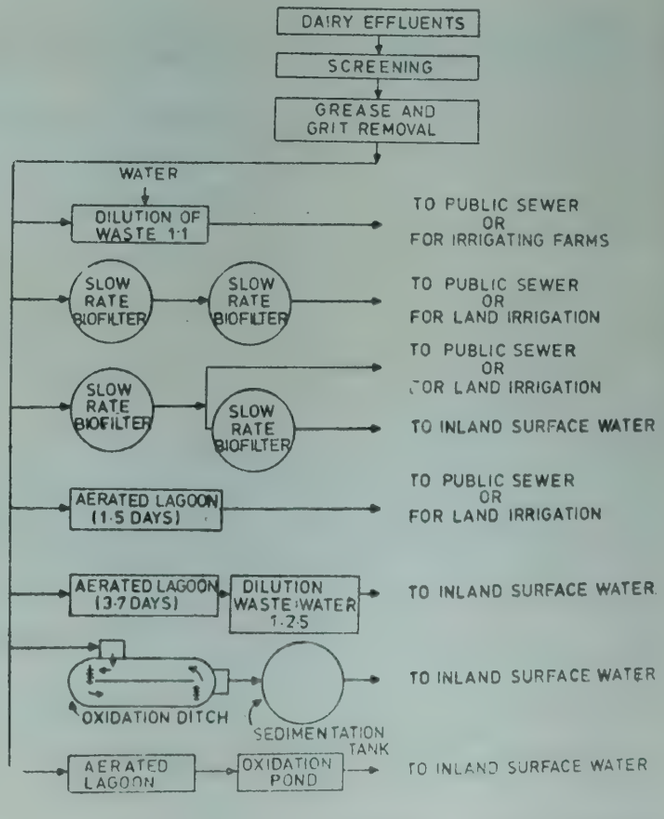

Fig. 1 Flow diagram for the treatment of dairy effluents.

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process is completely natural and takes 30-40 days for complete treatment. The BOD load to the stabilization pond will be 150-250 kg BOD/hectare/day depending upon the latitude of the place.

4. Recommended Treatment Method

The dairy wastewater treatment should consist of all the three, preliminary, primary and secondary treatment processes. As per Indian standards any industrial waste should not have BOD_5 values more than 30 mg/l, 500 mg/l and 500 mg/l, for discharging it into natural surface water, in public sewer or to use it as irrigation water respectively. Taking all these factors into account a complete flow diagram for the treatment of dairy wastes is plotted in Fig. 1. The selection of the treatment method should be done depending upon the end use of treated effluent and economic feasibility of the plant.

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Abattoir Wastes and Their Disposal

D. M. Bailur

Deonar Abattoir, Municipal Corporation of Greater Bombay, Maharashtra

Urbanization of industrial set-up has prevailed upon us to tackle the issue of disposal of their waste products, in such a way so as to render the same not only innocuous, but also to convert these waste products into useful or usuable products, by suitable treatments. With the result the disposal not only becomes easy but also inexpensive or on the other hand a paying resource.

Now what is a waste product? The answer will differ depending upon the time, place, circumstances, situation, expectation of standard etc. By and large, one would say what is not useful or what is useless, is to be termed as "waste". This again is a matter of individual consideration. For what is a "waste" to one may not be a "waste" to the other, placed altogether in different circumstances. However, a product to be termed as a waste, by and large, in general concept may be such:

(*i*) The material derived as un-usable part product, remnant etc. in that particular industrial set-up.

(*ii*) Further it may cause nuisance of sight, smell or danger to health or social or otherwise, nuisance.

(*iii*) Causing much inconvenience to the society at large, in direct or indirect form and calling upon its proper disposal.

1. Abattoir Waste

As far as abattoir or slaughter house is concerned, there are a number of items, which were and even today are considered as waste products and their proper disposal has become an important part of the slaughter house projects and planning. This part has been considered very vital because of the potentials of creating serious health—hazards in the society. The problem would aggravate by easily attracting rodents, birds, insects, cats and dogs, vermins etc. if proper precautions are not taken for systematic disposal of its waste products. In tropical climate, this problem has to be tackled, with special care, as it would prove a serious health hazard to the human population.

2. Disposal

2.1. The text books and the recent literature on the slaughter house operation, design and construction, have enumerated various methods of disposal of the slaughter house waste. Most of them are based on the same general principles of disposal of waste. Of these methods of disposal which are suitable at a particular place will however, depend on the local conditions and the resources available thereat.

2.2 *Principles involved are:*

(1) Dilution

(2) Dehydration-Drying

(3) Neutralisation

(4) Conversion.

Some of the methods are:

(*i*) Separation of the solid materials from liquid,

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(*ii*) subjecting to sun-drying of both solid or liquid wastes in open (in country side),
(*iii*) drying with such reagents so as to neutralize and thereby remove or minimize the nuisance,
(*iv*) dilution of the affluent material to the maximum possible extent to render the same as much harmless as possible or at least, less harmful,
(*v*) chemical treatment to neutralize, deodourize, disinfect and sterilize etc.
(*vi*) thermal treatment, autoclaving,
(*vii*) dry rendering,
(*viii*) burrying, and
(*ix*) incineration.

2.3. Dry matter when separated from the fluid, could be treated in one of the above mentioned suitable methods and subsequently burried, incinerated or otherwise treated, as the case may be. The liquid material after treating or rendering harmless or less harmful, with suitable treatment to a required B.O.D./C.O.D. standard, could be let out in the down streams of some flowing rivers or in general sewage system. However, care should be taken to comply with the prevailing inter-country or inter-state regulations or legislations, in adopting disposal methods. It is also very important to see that this should not pose any kind of danger to the habitation in the stream/out of stream in the areas along the down-streams of the river. This otherwise could pose a potential danger if the river water and the fauna in it, was to be made use of, for domestic purposes.

3. Factors Governing Design of Disposal System

3.1. Solving the disposal problems is of proven importance and therefore, it is necessary to thoroughly examine the arrangements of disposal from the following points of view:

(*i*) Distances of disposal point from the human habitation.
(*ii*) Proximity to water-resources & permanent water course.
(*iii*) Topography and land scapes.
(*iv*) Direction of winds.
(*v*) Nature of sub-soil condition.
(*vi*) Suitability of soil condition for sewage disposal and such others.

3.2. This needs further consideration of future developmental programme contemplated in that area such as residential or industrial colonies, national or international transport ways, proposed. Perhaps the present disposal system may pose a great problem for future development.

3.3. Furthermore, the details for the disposal requirements, the specific method of disposal and the arrangements thereof, will also depend upon:

(*i*) Nature of waste material,
(*ii*) volume,
(*iii*) through-put,
(*iv*) cycle of out-put,
(*v*) amount of water that is available for the process of disposal, and
(*vi*) primary or preliminary treatment that is possible and envisaged at the factory (slaughter house).

4. Utilization of Slaughter House By-products

4.1. From the very inception of human endeavour for procuring meat for food, since the pre-historic age, time and necessity have now and then, revealed to man that once so-called waste of a slaughtered animal has not remained a waste at all. As said "Necessity is the mother of invention" with the progress of man, kind in the urbanized society, the obligatory necessity of disposal of animal-originated waste product, has compelled him to invent ways and means of treating, processing, or rendering, as would be useful to him in one form or the other. Thus the products of the slaughter house to-day are subjected to various methods of processing, depending upon the nature of the original product, or the kind of end product expected of, and these are remunerative to either directly or indirectly and in cash or in kind. Hides and skins for example, which in the time immemorable of pre-homo-sapien was thought to be, of no use to him. It is probably the first product from the animal that the man has put to an useful purpose and it is considered as one of the most-useful by-products from the salughter house, fetching highest return. This, once a waste product has now become one of the largest foreign-exchange earner to the country. Subsequently, one by one, other waste-products were being converted for useful purposes.

4.2. To-day the slaughter house waste are, no more, called as wastes, but are called as slaughter house by-products, as each one of them is put to use in one way or the other by suitably processing. It would be proper to designate the whole subject as "Utilisation of Slaughter House By-products" instead of "Disposal of Slaughter House Waste." It is said, by some slaughter house experts that if proper systematic, organised methods are incorporated as recommended in the modern literature for utilization of by-products, there is nothing that goes as waste from a sluaghter house but for the "cry" of the animal.

5. Deonar Abattoir

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are made and most of these are properly collected and utilized to the best possible extent.

For utilisation of such products, which are of great pharmaceutical importance, necessary hygienic standards in maintenance of slaughter house premises, machinery set up, receptacles and in the slaughtering operations, the inspection standard of both ante-mortem and post-mortem, and skilful collection of the by-products for its pharmaceutical and medicinal uses, is of foremost importance. Only since the inception of Deonar Abattoir at Bombay, hitherto waste products from the slaughtered animals, are being put to the pharmaceutical use on a large scale.

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(*iv*) Ovaries — Pharmaceutical
(*v*) Thyroid — Pharmaceutical
(*vi*) Spinal cord — Pharmaceutical
(*vii*) Stomach (glandular) — Pharmaceutical
(*viii*) Kidney — Pharmaceutical
(*ix*) Guts — Commercialas in surgical
(*x*) Bone — Commercial bone-meal
(*xi*) Fat — Commercial
(*xii*) Horns & hoof — Commercial
(*xiii*) Skins & hides — Commercial

SLAUGHTER HOUSE BY-PRODUCTS AND THEIR UTILISATION OF

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(*iv*) Serum—substitute for egg albumin
(*v*) Pudding, sausages

B Processed Blood Meal
(*i*) Stock & poultry feed
(*ii*) Foam compounds
(*iii*) Hydrolysis—amino acids
(*iv*) Fertilizer
(*v*) Albumin
(*vi*) Weatherproof glue
(*vii*) Textile sizing
(*viii*) Dye-setting

II Hide and Skin

A Leather
(*i*) Harness, sadlary, whips
(*ii*) Industrial belts
(*iii*) Upholstry
(*iv*) Bindings (books etc.)
(*v*) Luggage-bags
(*vi*) Handbags
(*vii*) Shoes, belts, gloves

B Leather Trimmings Fleshings
(*i*) Gelatin
(*ii*) Glue
(*iii*) Lathe-industry
(*iv*) Tallow
(*v*) Fertilizers
(*vi*) Washers (Taps)
(*vii*) Gelatin (hog skin)

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(*ii*) Felting
(*iii*) Lanolin (wool fat for cosmetics)
(*iv*) Brushes
(*v*) Fertilizer

IV Intestine Casings

A
(*i*) Sausage-enclosure
(*ii*) Surgical ligature
(*iii*) Sports gutting
(*iv*) Musical instruments strings

B Stook feed
(*i*) Poultry feed
(*ii*) Pig feed

C Mucus
(*i*) Enzymes
(*ii*) Heparine

D Tallow

E Pepsin
Hog casing

F Surgical Substitute
Blood vessel parts

V Bones

A Bone Meal
(*i*) Stock & poultry feed mineral supplement

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(*ii*) Calcified-bone
(*iii*) Bone-black (bone charcoal) (very hard)-Sugar refinery—steel industry
(*iv*) Fertilizer

B Ossin
(*i*) Glue
(*ii*) Gelatin

C Lard-Tallow

D Handicraft
(*i*) Cutlary handles
(*ii*) Bone buttons, dice

VI Trotters

A Tendons
(*i*) Glue
(*ii*) Gelatin

B Neats foot oil

C Stock-feed

VII Hooves and Horns

A Handicraft
(*i*) Ornamental fancy articles
(*ii*) Buttons, combs, hairpins

B Horn Meal
(*i*) Fertilizer
(*ii*) Foam products
(*iii*) Glue (match & leather industry)

C Hornpith
(*i*) Gelatin

VIII Condemned Meat Offal, Trimmings

A Meat meal
(*i*) Stock and poultry feed
(*ii*) Fertilizer

B Fat (Commercial)

IX Fat

A Cooking fat–edible

B Lard and Tallow
(*i*) Soap
(*ii*) Stearin
(*iii*) Candles
(*iv*) Lubricants/machine oil
(*v*) Leather dressing
(*vi*) Textile industry
(*vii*) Stock & poultry feed supplements

C Glycerine
Pharmaceutical uses

X Dung-Stable-Effluents

(*i*) Compost
(*ii*) Gobar-gas
(*iii*) Fertilizer
(*iv*) Fuel cakes-light-power-heat

XI Glands

A Bile or bile stone or gall stone
(*i*) Bile salts
(*ii*) Cholic acids
(*iii*) Pigments
(*iv*) Medicinal use

B Pancreas-extract
(*i*) Pancreatin
(*ii*) Insulin

C Ovary
(*i*) Ovary extract

D Kidney
(*i*) Tissue for vaccine culture for F & M virus

E Adrinal

F Thyroid

G Pituitory

H Liver
(*i*) Lecithin cosmetics
(*ii*) Lard tallow

I Spinal cord

J Lungs
(*i*) Lecithin
(*ii*) Heparin

K Mucus-Enzyme-Extract-Heparin

L Stomoch-gastric glands
(*i*) Pepsin-tripsin (Hog)
(*ii*) Rennin (Calf)

M Placenta-Uterus

XII Floor Washing

(*i*) Fat
(*ii*) Meat trimmings-fleshings
(*iii*) Gobar-gas plant-Fuel gas

XIII Paunch Contents

(*i*) Compost
(*ii*) Fertilizer
(*iii*) Fuel gas
(*iv*) Fuel by dried cakes

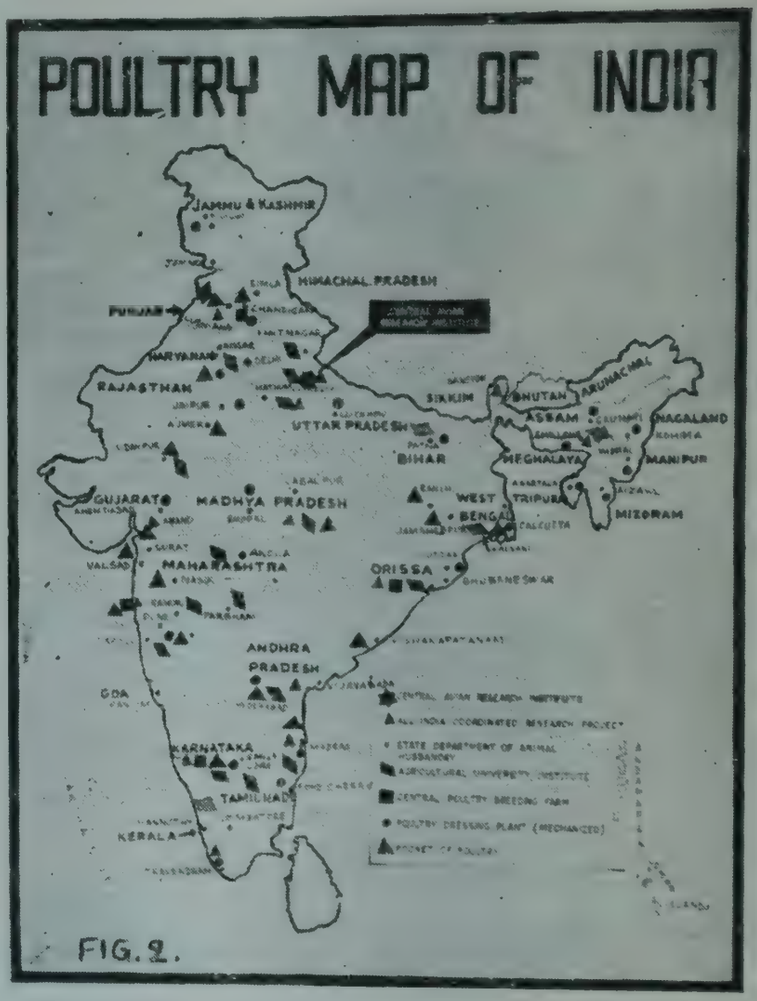
Processing and Utilisation of Poultry Industrial By-products

B. Panda and R. P. Singh
Central Avian Research Institute, Izatnagar, Uttar Pradesh

Utilisation of indigenously available organic wastes for meeting the shortages of raw material for industry and inputs for agriculture is an important aspect of our national economy. Serious and concerted efforts in this direction can not only reduce the cost of production and give economic return to the producers but also solve the disposal problem and minimize pollution hazards.

With the rapid development of poultry industry in India as evident from the number of firms, organizations and institutions which have sprung up during the last decade as well as a large scale investment by public and private sectors, large quantities of wastes from various facets of this industry, such as, farm itself, egg and poultry processing units, hatcheries, etc. are available.

Fig 1 shows the progress of the Indian poultry industry during the last two decades, while Fig. 2 presents the poultry map of India. The potential importance of these wastes/by-products as an inexhaustible



store of valuable economic products, such as, feed, fuel, and fertilizer, etc. has been stressed number of times. A good deal of work has been carried out in our country for their effective and economic utilization but for practical purposes, they are not being utilised properly. No industry can make a headway unless it utilizes its by-products efficiently.

An attempt has been made here to present the available information on the various wastes/by-products of poultry industry which have hitherto been neglected or partially utilised and the various economic products which can be obtained therefrom.

1. Poultry Processing Wastes

Yield: Poultry processing plant wastes include head, feet, feathers, blood and viscera which constitute around 26 to 29 percent of live weight of the birds. Every kilo weight of live bird processed will leave 35 g of blood.

80.7 g of feathers, 30 g of head, 39 g of feet, 9 g of lungs and 80 g of viscera, making a total waste of 273.7 g, which works out to 27.37% of total offals[1]. Collectable by-products expressed as the mean yield per 1000 kg live weight of broilers has been reported as follows:: feathers, 54 kg; blood, 37 kg; offal or viscera, 118 kg; feet, 30 kg; lungs, 9 kg; unwholesome carcasses, 10 kg; fat and grease, 6 kg and settling or sludge, 10 kg.

Neelakantan[3] assumed the by-product meal yield as 20 per cent. The percent yield of poultry by-product meal, processed at 1 kg/cm^2 pressure for 45 min, was 24.82, 27.20, 27.90 and 22.95 for broilers, growers, culled hens and cocks, respectively[4]. The percent yields of feather meal, blood meal and by-product meal, expressed over live weight, are given in Table 1.

TABLE 1. PERCENT YIELDS OF MEALS OVER LIVE WEIGHT[5]

	Feather meal	Blood meal	By-product meal
Broiler	5.5	0.78	5.16
Fowl	5.5	0.67	4.27
Turkey	5.9	0.78	4.17

From the above statements, it appears that there is no standard yield of inedible wastes during processing and the variation is due to type and age of the birds and processing methods.

2. Processing, Chemical Composition and Utilisation

Different by-products are processed either separately or in combinations, such as, feathers alone, offals (head, feet and viscera), blood, feathers and blood, offals, blood and feathers and offals and blood. Thus, the chemical composition and utilization of by-products meal varies with the composition of raw materials and processing methods used.

2.1. *Feather meal*

Feather meal is the product obtained from pressure cooking of clean, undecomposed feathers from slaughtered poultry to a point where the protein becomes friable and digestable. Not less than 75% of its crude protein content must consist of digestable protein. The chemical composition of hydrolysed feather meal is given in Table 2. Approximately 85 to 90% of protein from feather meal comes from keratin[6]. The high cystine content in the feather keratin is probably the limiting factor in the utilization of feather protein. Commercial processing of feathers has been shown to result in extensive cystine degradation.[7] The nutritive value of feather meal largely depends upon the method and efficiency of hydrolysis. During steam hydrolysis along with lime, some of the amino acids such as arginine, isoleucine, serine and threonine may be lost[8]. It is suggested that 142-153°C (40-60 lb/inch^2) for 30 to 60 min is most suitable for feather meal production[9]. Feather meal prepared at 3 kg/cm^2 pressure for 30 to 60 min had higher available lysine, methionine and *in-vitro* pepsin digestability[10].

TABLE 2. NUTRIENT COMPOSITION OF INEDIBLE BY-PRODUCTS[23,30,50,51]

Components	Feather meal (Hydrolysed	Poultry blood meal	Poultry product and meal	Poultry by-product feather meal combined
Moisture %	6.0	5.8	9.0	8.0
Crude protein %	85	56.4	72.0	55.9
Ether extract %	6.7	16.1	3.1	21.7
ME (Kcal/kg)	2354	2860	2685	3610
Ash %	3.9	14.6	3.0	11.8
Calcium %	0.2	3.5	1.50	3.9
Phosphorus %	0.75	1.7	0.64	0.8
Vitamins				
Riboflavin (mg/lb)	0.09	4.0	—	—
Niacin (mg/lb)	8.0	40.0	—	—
Pantothenic acid (mg/lb)	3.7	4.0	—	—
Vit. B_{12} (μg/lb)	39.0	129.0	—	—
Choline (mg/lb)	400.0	2700.0	—	—
Amino acids				
Arginine %	5.6	3.8	5.2	4.43
Glutamic acid %	10.7	5.5	—	—
Histidine %	0.6	0.8	4.1	1.13
Lysine %	2.1	3.7	6.8	2.42
Leucine %	7.4	4.2	8.6	4.38
Isoleucine %	5.3	1.8	3.0	2.57
Methionine %	0.5	1.0	1.2	0.61
Cystine %	3.1	1.0	0.8	3.19
Phenylalanine %	4.7	1.8	4.8	2.60
Threonine %	5.0	2.4	3.9	2.61
Tryptophan %	0.6	0.7	1.9	—
Tyrosine %	2.8	1.5	2.1	1.71
Valine %	6.5	2.9	6.3	3.66
Glycine %	6.8	2.9	4.4	4.87
Digestability %	87.5	88.5	97.7	77.0

2.2. *Feather meal as feedstuff*

Feather meal cannot be used as a sole protein supplement because some of the aminoacids like lysine, methionine, histidine and tryptophan are deficient in it. Owing to its poor amino acid profile, the use of feather meal is limited to the extent of 4—5% in the poultry ration or as a substitution of fish meal upto a level of 25%[10]. Better

chick growth has been reported[11] when feather meal was used to supply 2.5% protein along with blood meal. Literature[12-15] available indicate that feather meal could be used in chick and broiler diets to supply approximately 25% of the protein requirement. Hydrolysed feather meal added to 5.0% with 3.77% ground yellow corn in place of 8.77% soybean meal in ration and fed to turkey poults from one day to 8 weeks of age did not affect body weight but decreased feed consumption and increased feed efficiency by 1.9%[16].

2.3. *Other uses of feathers*

Besides livestock feed, dry feathers of chicken, turkey and ducks are commonly used for making pillows, sleeping rugs, quilts and sporting goods. Simply cooked feathers can be used as fertilizer and filler for chemical fertilizer.

2.4. *Offal meal*

Offal meal, commonly known as poultry by-product meal (PBPM), consists of ground, dry or wet rendered clean parts of the carcass of slaughtered poultry, such as heads, feet, intestines, lungs, wind pipe, oil glands, exclusive of feathers.

Poultry by-product meal is prepared[10, 17] by cooking the raw materials in conventional dry rendering cooker or in autoclave at 1 kg/cm^2 pressure for 30 min. After cooking, the excess fat is separated and dried at 70°C for 18 hr and finely ground. Antioxidant, such as, butylated hydroxytouline (BHT) at the rate of 0.02% is added to the ground material before packing is done.

The chemical composition of poultry by-product meal is given in Table 2. Aucker *et al*[18] studied the nutrient composition of poultry offal and found the digestable protein to be over 91% of the crude protein content.

Poultry by-product meal has been found to be a good source of protein in broiler ration[19] and can be satisfactorily used upto 12% of the ration without any detrimental effect on growth rate.[29] The PBPM could replace fish meal to the extent of 75% on isonitrogenous basis in broiler chick ration.[4]

2.5. *Blood meal*

Blood meal is ground, dried blood. The fresh blood, to which anticoagulant such as 10% sodium citrate solution (at the rate 10 ml to every 100 ml of blood) is added, is transferred to a tank where it is coagulated by steam, water is drained off and the caogulum is dried in a steam jacket drier. Since the temperature and time in the drier are automatically controlled, a uniform and high quality product is obtained. The average yield and chemical composition of blood meal are given in Table 1 and 2, respectively.

Sometimes, feathers and blood are processed together because of the small volume of blood collected does not warrant separate rendering of this material. Moreover, the amino acid profile of blood meal complements the poor profile of feather meal.

2.6. *Mixed poultry by-product meal*

A combination of offal meal, feather meal and blood meal, known as mixed poultry by-product meal is more balanced product nutritionally. The procedure for preparation of mixed by-product meal is similar to that of offal meal. In some cases, renderers first hydrolyse feathers and then add offals. In all these processes, the product has to be sufficiently treated to destroy the micro-organisms. The chemical composition of mixed by-product meal is given in Table 2.

Wisman *et al*[21]. found hydrolysed feather meal and poultry by-product meal to be satisfactory source of animal protein in grower, broiler and layer rations, when used to replace one sixth of the crude protein content. Mixed poultry by-product meal fed to supply 5% protein in chick diet, had higher nutritive value than diets containing only feather meal[22]. Feather and offal meal can be used upto a level of 10% and 12.5%, respectively as a replacement of fish meal in broiler and layer rations without affecting growth in broilers and production in layers[23]. Portsmouth[24] recommended that mixed poultry by-product meal can be used upto 5% in chick and broiler rations, 7.5% in growing pullets, laying hens and breeders, 2.5% in turkey poults and 7.5% in fattening turkey rations.

2.7. *Shank soup*

The chicken shanks, generally categorised as inedible poultry by-product, can be processed for preparation of soup[25]. The process consists of cooking the fresh and clean shanks at 15 lb pressure for 15 min along with spices and sufficient quantity of water (1.5 litre per 100 shanks). About 8 to 10 cups of soup could be prepared from 100 shanks. The soup so prepared is rich in nutrients and has nice aroma and taste.

3. Hatchery Wastes

Poultry hatchery wastes consist of infertile eggs, dead embryos, empty egg-shells, unhatched eggs and unusable chicks. There is good scope for availability of these wastes through fast expanding hatcheries which when converted into feedstuff would provide good source of animal protein, mineral and amino-acids for livestock including poultry feed.

3.1. *Processing and chemical composition*

To produce high quality hatchery by-product meal (HBPM), it is essential that the raw material be managed to prevent decomposition. The most desirable procedure[26] to accomplish this would be to process the wastes immediately after collection by cooking for one hour and drying them at 80°C for about 8 hours in a drier. The dried material is ground after addition of antioxi-

TABLE 3. PERCENT CHEMICAL COMPOSITION OF THE TWO TYPES OF PROCESSED HATCHERY WASTES[52]

Constituents	Broiler hatchery by-product	Egg type chick hatchery by-product
Original water	65.00	71.00
Protein	22.20	32.20
Fat	9.90	18.0
Calcium	24.60	17.20
Phosphorus	0.33	0.60
Amino acids		
Aspartic acid	1.93	2.83
Threonine	0.88	1.27
Serine	1.04	1.70
Glutamic acid	3.34	5.15
Proline	1.87	2.78
Glycine	1.48	2.46
Alanine	1.04	2.10
Cystine	0.57	0.65
Valine	1.39	2.07
Methionine	0.62	0.77
Isoleucine	1.22	1.70
Leucine	2.01	3.00
Tyrosine	0.37	0.96
Phenylalanine	0.85	1.48
Histidine	0.04	0.57
Lysine	1.16	1.83
Arginine	1.59	2.35
Total	21.79	33.67

dant (BHA) at the rate of 0.20% for proper preservation. Dry-heat dehydrating process is also followed for preparation of HBPM.

The chemical composition of HBPM is given in Table 3. The chemical composition of waste products varies with the efficiency of the hatchery operating procedures. Improved hatchability decreases the protein level and increases the calcium content of HBPM. Gross protein value of hatchery by-product meal has been reported[27] to be 86.5 compared to 86.4 for fish meal.

3.2. *Hatchery by-product as feedstuff*

Feeding trials with dried contents of incubated eggs to the growers have shown that growth and feed efficiency to 10 weeks of age were not altered when 16% of the material replaced a mixture of meat scrap, dried skim-milk and fish meal[28]. Similarly, hydrated hatchery waste has been successfully fed to the chicks upto 8 weeks of age at 3% and 6% levels of total as protein replacement by soybean oil meal or meat scrap[29]. It was found that when 4.6% HBPM was used to provide 1.2% protein in broiler diet, the growth was superior compared to basal diet[30]. Hatchery by-product meal could be included in layer diet upto 8 to 15% level without any deleterious effects on feed efficiency, egg production and egg weight[31,32].

3.3. *Damaged eggs*

Around 6 to 12 per cent of total eggs produced in the country do not reach consumers' table and are damaged either at farm, process of gathering, packaging, transit or storage and marketing. In egg processing units, around 11% of raw material as waste in the shape of shell and around 5% as unsound eggs are obtained while preparing further processed products. The damaged and eggs of poor quality can be salvaged by production of albumen flake, dried/frozen yolk as semen extender and egg shell meal as livestock feed.

3.4. *Albumen flake*

The albumen is separated from the yolk, homogenized, de-sugared either by enzyme or yeast or bacterial fermentation and the fermented albumen is dried in a cabinet drier at a temperature of 56-58°C for 12 to 14 hours. Pancreatin or trypsin is added to help break-down of thick white to thin white. The moisture of the product is brought down to 7% or less, packed in air-tight tins and can be stored for about 6 months at room temperature. This product has great demand by textile, printing and other industries.

3.5. *Egg-shell meal*

Process for preparation of egg shell powder from egg shells, egg powder and albumen flake from eggs has been standardized[26,33]. The process consists of breaking of shells to fragments, addition of equal quantity of water to recover albumen, treatment of shells with

TABLE 4. CHEMICAL COMPOSITION OF EGG SHELL MEAL[53]

Constituents (%)	Egg shell meal
Moisture	1.0
Crude protein	7.6
Ether extract	0.24
Total ash	91.1
Calcium	36.4
Phosphorus (available)	0.12
Amino acids	
Arginine	0.57
Glycine	0.51
Histidine	0.30
Isoleucine	0.34
Leucine	0.57
Lysine	0.37
Methionine	0.28
Tyrosine	0.25
Threonine	0.47
Valine	0.54
Trytpophan	—
Cystine	0.41

boiling dilute alkali to dissolve shell membrane and residual albumen, washing with water till free from alkali, drying at 100°C for 15 hours, powdering and packing in alkathene bags. About 5 kg of egg shell powder and 100 g of residual albumen could be recovered from about 1000 eggs at a cost of little less than Re. 1. The chemical composition of egg shell meal is given in Table 4.

Biological assay with albino rats has shown that egg shell powder could be used as sole sourse of calcium in diet[26]. The dried and coarsely ground shell can be used as a substitute for precipitated calcium carbonate and incorporated as a good source of calcium in poultry and livestock feeds.

4. Poultry Manure

Generally 100 laying hens will excrete about 10 to 12 kg of wet droppings per day. Higher moisture content (75 to 80%) of fresh droppings added with presence of pathogenic microorganisms makes direct feeding of manure difficult. When properly processed, both excreta from cage house and poultry house litter can be used for feeding ruminants and poultry, besides its traditional use as fertilizer.

4.1. *Dried poultry manure (DPM)*

Fresh droppings from cages are sun-dried to reduce the moisture content considerably. The sun-dried material is autoclaved at 15 lb pressure for 10 min and then dried in a forced draft air drier to reduce the moisture content to not more than 10%. The product thus prepared is ground to coarse granular form to be ready for use as dried poultry manure. However, poultry house litter can be processed in similar manner or ensiled as poultry litter silage before being fed to the ruminants.

The chemical composition of dried poultry manure is given in Table 5. On an average, the protein is 28%, out of which only 10 to 11% is true protein comparable to those in cereals. The rest of the nitrogen is non-protein nitrogen, mostly uric acid which can't be utilized by the birds. However, rumen flora are able to utilise it, ultimately producing true protein which can be well assimilated by the ruminants. The low metabolizable energy (350 to 1350 kcal/ kg) content of DPM places a limitation on its use in poultry rations.

4.2. *Manure as fertilizer*

The profitable disposal of poultry manure as fertilizer is well recognized[34-37]. They reported that poultry manure is not only a good fertilizer but also helps to improve the physical structure of the soil. The fertilising values of poultry manure are better than that of cow and sheep manure. One ton of deep litter containing 65 lb of nitrogen, 45 lb of phosphorus and 45 lb of potash has fertilizer constituents equivalent to 300-325 lb ammonium sulphate, 250-300 lb ordinary superphosphate and 100 lb potassium, respectively, together with 15 lb of magnesium, 15 lb sodium and 60 lb calcium[38]. Besides, poultry manure contains small amounts of trace elements, especially boron, copper, iron, sulphur and zinc. The fertilizing value of poultry manure depends on its care and management i.e. exposure to the leaching action of rain decreases its fertilizing value. One problem peculiar to poultry manure is that its nitrogen is quickly available so that if care is not taken in its application, burning occurs.

Biodegradation of raw manure either by microorganisms or fly larvae can be a profitable proposition since products available out of these acts are good fertilizer. In latter case, the wet manure can turn into crumbly

TABLE 5. AVERAGE CHEMICAL COMPOSITION OF DRIED POULTRY MANURE (DPM)[46]

Nutrients	Percent	Minerals	Percent	Amino acids	Percent
Dry matter	91.00	Calcium	4.61	Alanine	0.61
Crude protein	28.58	Phosphorus	2.20	Arginine	0.38
Crude fat	2.57	Sodium	0.42	Aspartic acid	0.71
Crude fibre	12.25	Potassium	1.37	Glutamic acid	1.12
Nitrogen-free extract	32.65	Copper (ppm)	61	Glycine	1.33
Total ash	23.95	Zinc (ppm)	325	Histidine	0.23
Acid insoluble ash	4.28	Manganese (ppm)	291	Isoleucine	0.36
True protein	11.00			Leucine	0.55
ME (kcal/kg)	790			Lysine	0.39
				Methionine	0.12
				Cystine	0.15
				Phenylalanine	0.35
				Tyrosine	0.27
				Serine	0.38
				Threonine	0.36
				Valine	0.46

wastes within 8 days and around 500 to 1000 lb of pupae can be grown on chicken excreta of 100,000 chicken. These pupae, when properly processed, can act as a good source of protein for growing chicks.

4.3. *Manure as livestock feed*

Litter containing 25-35% crude protein when given 25-30% of total ration of ewes and lambs was as good as soybean meal[39]. Poultry litter upto 40-50% levels have been tested for feeding dairy cattle and pigs[40,41]. However, pig can utilize a little but dairy cattle can consume and efficiently utilize large quantities of dried poultry manure[42]. Beef cattle fed on ration containing 3.5 CWT of DPM/ton have performed almost as well as on control diet[43]. Chauhan and Singh[44] reported that male calves getting 25% litter and litter silage concentrate mixture grew significantly better than calves on conventional ocncentrate diet.

Dehydrated poultry manure from layer betteries is more suitable for poultry feeding and could be included to the extent of 10-20% in rations of starting layer type, broiler starter, broiler finisher and growing chicks without any adverse effect on growth rate[45-48]. Layers have been kept on a continuous diet containing 12.5 to 25% of DPM, replacing corn in their diet for a period of 14 months with remarkable liability, feed conversion and egg production[49].

Efficient utilization of its by-products is the lifeline of an industry. Efforts have, therefore, been made in this paper to present some of the salient findings with regards to the processing and utilization of poultry industrial by-products.

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Brief Status of Waste Utilisation Activity in India

National Committee on Science & Technology, New Delhi

	Waste	Use and present position	Work done in Lab/Institution
1.	**AGRICULTURAL WASTES**		
1.1	Non-edible oil-seeds of neem, mahua, Kusum, Karanj and undi.	There are at present 80 different oil-bearing trees with an estimated annual production of about one million tonnes of minor oil seeds. More than 40% of oil-seeds come from neem and 20% from mahua. Only a fraction of these oil-seeds are collected and crushed in mills or in villages, totalling only about 70,000 tonnes. An efficient programme of collection and crushing of these oil-seeds can lead to a production of about 0.3 to 0.4 million tonnes of oil cakes along with considerable quantities of oils and fats for use in various industries like soap-making, medicine, etc. The oil cakes contain 2.5 to 5.2% of nitrogen and 0.8 to 1.6% of P_2O_5 and can be used as manure.	The Regional Research Laboratory, Hyderabad has worked out methods for splitting and recovery of fatty acids, from non-edible oils derived from these seeds.
1.2	Sal seeds available in forest areas particularly in Orissa.	There are about 40,000 tonnes of sal seeds produced annually.	As a result of research conducted by the ICAR and CFTRI arrangements have been made for the collection of sal seeds on a commercial scale and lately it is understood that the seeds are being used for extraction of oil. Investigations conducted on residual cakes show that this cake can be utilised for feeding poultry pigs and cattle.
1.3	Groundnut cake after extraction of oil.	It is used as a human food as it contains 45 to 50% of protein. At present, the groundnut cakes are generally used for cattle feed and also as fertilizer. It is estimated that annually 2 to 2.5 million tonnes of groundnut cakes are available in the country.	In CFTRI, Mysore, work has been carried out to make out of de-oiled groundnut cake different products of highly nutritive value. The work has resulted in the preparation of edible quality groundnut flour (free from toxic factors) which is now used as a component for high protein feeds like Bal Ahar, Multipurpose food and fortified atta. The work has also resulted in the production of protein isolate which can be conveniently used as protein fortifier in various foods.
1.4	Rice bran	At present, rice bran, a by- product of rice milling industry, is mostly used as a cattle feed. A limited amount is also being processed for extraction of industrial grade oil by solvent extraction. 6 to 8% of bran oil is recovered under the existing conditions of milling and the total quantity of rice bran estimated to be available is about 2.4 million tons in the country.	In CFTRI, work has been carried out to prepare rice bran oil that can be used for edible purposes. Processed for the production of amylase, amyloglucosidase and pectinase enzymes have been standardized by utilising wheat bran and de-fatted rice bran. The demand for these enzymes is 600 tonnes per annum. Process has also been evolved for producing activated carbon from rice bran.
1.5	Rice husk	Furfural; silicate refractories (silicon tetra-chloride), other chemicals; building materials (like cement).	Work is being done at RRL, Jorhat and IIT, Kharagpur.

1.6	Tea waste	At present, a large amount of tea waste of the order of 8,000 to 9,000 of tonnes is burnt. In the processing of tea, 2% waste is obtained which contains 2 to 3% of recoverable caffeine i.e. about 160 to 180 tonnes on total tea waste. Import of caffeine during 1969–70 amount to 5883 kg. valued at Rs. 1.27 lakhs.	The Regional Research Laboratory, Jorhat has developed a process for the production of caffeine from tea waste. It is claimed that the cost of production by the process developed at the laboratory would be Rs. 20 per kg, as against the present market price of Rs. 100-120 per kg. A plant with a capacity of 120 tonnes per year has been set up in Assam.
1.7	Bagasse (fibrous material left over by cane crushing in the manufacture of cane sugar).	Used mainly as fuel in sugar factories and partly in admixture with pulp for making of paper due to shortage of conventional cellulosic materials, like bamboo, hemp, etc. In that case, a cheaper fuel than bagasse has to be investigated. Production of cane sugar in 1969–70 was 4.2 million tonnes. From 8 T of cane crushed one tonne bone dried bagasse is obtained. The quantity of bagasse available can be estimated at 5.25 million tonnes. Dry bagasse consists essentially of fibre and pith. The fibre content is about 65% of dry weight and the pith including soluble matter constitutes the remaining 35%. The fibre is suitable for manufacture of paper of good quality. The pith, on the other hand, has no value as a paper making material and pulping of the bagasse containing pith leads to larger consumption of chemicals used for digestion, difficulties in washing and bleaching the pulp, slow rate of draining of the stock on the paper machine and less capacity of the resulting paper. It is, therefore, necessary to separate the pith from the fibre for the manufacture of paper. The separation of pith has to be undertaken in the sugar factories in order to reduce the bailing, storage in transport charges on the bagasse meant for paper production. The pith can be used as a fuel in the sugar factory. On the basis of 5.25 million tonnes of dry bagasse available in 1969–70, it can be calculated that about 3.34 million tonnes of fibre would be available for paper manufacture.	Ministry of Industrial Development sponsored a study on utilisation of bagasse for paper making. The scheme did not make much headway because the sugar mills wanted some subsidy from the Government to convert their bagasse burning boilers into oil or coal burning boilers. Similarly, they found that the sale proceeds were less than what they would have to pay for the purchase of coal. Bagasse containing 45 to 50 per cent moisture has a calorific value of about 4,400 BTU/pound as against 12,600 BTU/pound of coal of good grade. Thus, in terms of fuel value coal bagasse is 5:2 i.e. on weight basis, one tonne of Grade I coal would replace 2.5 tonnes of bagasse provided the boilers in the sugar mills are of the type which can switch over to coal without any modifications.
1.8	Tobacco waste	The present amount of tobacco waste is estimated at 62,000 tonnes. Out of this, two-third is used for manurial purposes and to some extent as insecticide and the remaining one-third is wasted. Tobacco contains one to three per cent nicotine.	At the National Chemical Laboratory a process has been developed for the production of nicotine sulphate solution (40% nicotine) from tobacco waste. The process has been released to four parties for exploitation. Besides nicotine sulphate, manufacture of nictotine acid can also be taken up as a by-product of nicotine sulphate industry.
1.9	Proteins from plants	Considerable amount of protein can be extracted from plants. Also from trees polysaccharides, lipids and proteins can be extracted. An extraction devise has been evolved in the plant protein research units of Indian Statistical Institute.	Indian Statistical Institute, Calcutta, NCL Poona, FRI, Dehradun, ICAR Laboratories have shown the potential in their laboratory investigations.
1.10	Saw-dust	Utilized in a number of ways as is evident from the following list: (*i*) Activated carbon using saw-dust from softwood (*ii*) Oxalic acid from saw-dust (*iii*) Phenolic moulding powder from saw-dust (*iv*) Particle board from wood-waste without binder (*v*) Hardboard from saw-dust (*vi*) Woodwool waste board from wood-dust (*vii*) Distillation oil from the saw-dust of *Eucalyptus* (*viii*) Furfural from saw-dust (*ix*) Protein food from cellulosic materials	Laboratory level work being carried out at the following places: RRL, Hyderabad RRL, Jorhat RRL, Jorhat RRL, Jorhat; IPIRI, Bangalore RRL, Jammu; IPRI, Bangalore FRI, Dehra Dun FRI, Dehra Dun NCL, Poona

		(*x*) Fuel oil from cellulosic wastes	RRL, Hyderabad
		(*xi*) Saw-dust as a mulching material	
		(*xii*) Saw-dust as a bedding material for animals	
		(*xiii*) Saw-dust as a manure in tropical soils	
		(*xiv*) Saw-dust as a packing material	
		(*xv*) Alcohol from saw-dust	
1.11	Other agricultural wastes	(*a*) Production of furfural alcohol	RRL, Jorhat
		(*b*) Use in paper and pulp industry	FRI, Dehra Dun
		(*c*) Agricultural wastes and by-products as cattle feed	
		(*d*) Preparation of activated carbon	
		(*e*) Fire retarders from cashewnut and arecanut oils/resins	CBRI, Roorkee
		(*f*) As manure	CPHERI, Nagpur
		(*g*) Use of cotton dust of textile mills for making compost	RRL, Jorhat.

1.12 COCONUT WASTES/BY-PRODUCTS (OTHER THAN THOSE USED FOR CONSTRUCTION MATERIALS)

1.12.1	Coconut shell	About 0.88 m. tonnes of shell are available. At present used as fuel and for manufacture of fancy articles and miscellaneous household articles.	NCL, Poona-destructive distillates for coconut shell. FRI, Dehradun/IRIRI Bangalore coconut flour as a filler for synthetic resin, glues, filter and extender for phonolic moulding powder.
1.12.2	Coconut husk	About 6,000 million tonnes is available in coconut producing areas. Only 50% is used in the coir industry.	FRI, Dehra Dun-high stretch paper with 10% long fibre pulp.
1.12.3	Coconut water	About 0.5 million tonnes of water is available. Used only as a soft drink.	Manufacture of antibiotics. As a rubber coagulant. As a source of potash in agriculture. In vinegar manufacture.

1.13 ARECANUT WASTES/BY-PRODUCTS (OTHER THAN THOSE USED FOR CONSTRUCTION MATERIALS)

1.13.1	Arecanut husk	1 lakh tonnes available. Used as a poultry feed.	FRI, Dehra Dun-brown wraping paper CPCRI, Regional Station, Vittal is collaborating with various agencies to find out its economic uses.
1.13.2	Leaf sheath	About 90,000 T/annum available in the country used as a thatch or making brooms.	No significant work has been done.
1.13.3	Chogaru liquid or 'Kali'	No estimate available. At present wasted.	CLRI, Madras-tannings from 'Kali'.

1.14 CASHEW WASTES/BY-PRODUCTS (OTHER THAN THOSE USED FOR CONSTRUCTION MATERIALS)

1.14.1	Cashew apple	About 30m tonnes available. Used for 'Feni' preparation in some regions.	CFTRI, Mysore-preparing a variety of beverages, liquors and other products after removal of astringent and acrid principles.
1.14.2	Cashew testa	About 3-4 thousand tonnes available. It contains about 61% tannin. At present used for only burning in the factories.	CLRI, Madras, has developed a process for extraction of tannin from cashew testa.
1.14.3	Cashewnut shell liquid	About 10-14 thousand tonnes available. Only 1,000 tonnes indigenously used. Finds applications in the paints, varnishes, automobile and foundry industries.	RRL, Hyderabad NCL, Poona

1.15. COTTON WASTES/BY-PRODUCTS

1.15.1	Cotton stalks	Approx. 25m T. available/annum. Used as fuel in villages	No significant work done. Can be used as raw material for dissolving grade pulp/hard board packing material.

1.15.2	Cotton leaves	No data available. These are a rich source of organic acids.	IARI, Delhi has done work on their organic and acid content (citric aicd, malic acid etc.)
1.15.3	Cotton linters	Available in A.P., Bombay, M.P., Madras, Mysore, Punjab, Rajasthan and U.P. etc. Seed with linters used as cattle feed and also for sowing.	Can be used for acetate rayon, cellulose lacquers etc. RRL, Hyderabad, NCL, Poona and CTRL, Bombay are working on chemical diluting of cotton seed and other related aspects.
1.16	JUTE WASTES/BY-PRODUCTS		
1.16.1	Jute stick	About 2.5m tonnes available from 64 jute growing districts. At present used only for burning and fencing purposes.	JTRL, Calcutta has worked out the possibility of converting jute stick to paper, box board, particle board, viscose rayon, etc.
1.16.2	Jute mill waste	This consists of caddis, comprising short fibres and fluff, jute waste & the shaken dust. Total quantity available may amount to 50,000 tonnes. At present used as a supplementary fuel in boilers.	No work has been done.
1.17	WOOD WASTES		
1.17.1	Saw-dust	(*See item 7 above*)	
1.17.2	Bark from industrial wood like veneer logs	About 0.3m tonnes available. Used only for burning purposes.	FRI, Dehra Dun has initiated some work on 'chemicals from wood distillates'.
2.	COMMUNITY WASTES		
2.1	Night soil, sewage sludge, cattle dung, urine	Only in few cities and towns, there is an efficient sewage disposal system which gives rise to sewage and treated sludge as manures. Sewage sludge contain high nutrients. The annual potential quantity of nitrogen, P_2O_5 and K_2O available from the night soil and urine in the country is estimated at about 7 million tonnes of dry matter containing 2 million tonnes of nitrogen, 0.5 million tonnes each of P_2O_5 and K_2O	The Central Public Health Engineering Research Institute Nagpur has developed a process for making manure and fuel gas from night soil sewage sludge and cattle dung. The gas is used for its fuel value. The digested matter can be used as soil conditioner as it has manurial values.
2.2	City refuse	Arrangements for night soil compost making is too inadequate in many cities. However, in recent years, composting of town refuse and night soil in trenches are being practised and advocated. About three million tonnes are being prepared annually. The total quantity of nitrogen thus saved and used for manuring land works out to be less than 10% of the country's potential. Survey regarding viability of composting in different areas and innovations in mechanical composting need to be done.	The Central Public Health Engineering Research Institute has made compost from city refuse yielding a very good material for soil conditioning. Jadavpur University, IIT, Kanpur.
2.3	Slaughter-house wastes	The total loss sustained by the country in respect of non-utilisation of animal by-products and wastes is estimated to be Rs. 29 crores per annum. Moreover, the by-products can be used for the production of various products like stearin, casings, gelatin, poultry feed, etc. The country produces about 27,000 tonnes of animal intestines per annum. Most of these go waste. One per cent of these is only exported to earn Rs. 120 lakhs per annum as foreign exchange. It is estimated that nearly two-third of the 55,000 tonnes of blood available is wasted which is valued at about Rs. 1 crore. Animal blood when dried produces blood meal containing 10 to 12% nitrogen and 1 to 2% of P_2O_5 which after proper sterilization could be used as a top-class stock feed. Nearly 12 million carcasses of large animals are available annually. Excepting hides, horns and bones, the rest are allowed to go waste. Slaughter-house meat waste, if processed, would give rise to 0.12 million tonnes of meat meal manure.	The Central Leather Research Institute has developed a process for making blood meal out to this waste. Its suitability in poultry feed formulations has bene established. Work is also done in IVRI, Izatnagar and other ICAR laboratories regarding utilisation of the wastes from dead animals-raw bone meal, meat meal, Glue Gelatine. A report by CSIR has published the work of task force on "Abattoirs and Animal Products" headed by Dr. Parpia of CFTRI, in 1972.

3. ANIMAL WASTES

3.1	Fisheries wastes	(*i*) Agar-agar, agarose and sodium alginate from seaweeds	Work is in progress at CSMCRI, Bhavnagar
		(*ii*) Animal food production from waste water	NBG, Lucknow and CFTRI, Mysore have initiated work.
		(*iii*) Fish protein concentrate, fish meal from laboster wastes; sharkliver residue etc.	RRL, Bhubaneshwar has done some work.
		(*iv*) Proteins and amino acids from marine algae.	CSMCRI has initiated work.
		(*v*) Shrimp waste as poultry feed	CFTRI has carried out laboratory level studies.
		Also item 15-Slaughter house wastes.	
3.2	Prawn wastes	About 40,000 tonnes of prawn wastes in the form of head and shell are available from the processing factories. At present it is used only as a manure or cattle/poultry feed.	CIFT, Cochin has prepared chotosan which has good potential in textile and also a product called shrimp extract for human consumption.
3.3	Squilla	About 1,00,000 tonnes are annually caught but is normally thrown back into the sea.	No significant work has been done. Squilla is a good source of chitosan an important chemical for the textile industry.
3.4	Frog wastes	About 5,000 tonnes of this waste is annually available in the form of body and fanc-legs	No work has been done. It is reported that frog oil is beneficial in the treatment of 'ashtma'.
3.5	Carcasses utilisation	It is estimated that about 125 lakh carcasses of large animals are annually available. Usually only the hide and some of the bones are collected while the meat, fat, horns, hoofs, etc. are allowed to go waste. Due to defective flaying and improper curing the country losses Rs. 5 crores annually and Rs. 22.5 crores through non-utilisation of the other components of carcasses.	KVIC has formulated various schemes for the development of carcass utilisation by co-operative societies etc. The Madras Veterinary College has also set up a 'Flaying Section' to impart training in scientific flaying and curing of hides to amateurs and butchers since 1953.

4. MISCELLANEOUS WASTES FROM THE FRUIT AND VEGETABLE PROCESSING INDUSTRIES

4.1	Mango peels & kernels	These constitute about 50% of the weight of fresh mangoes.	CFTRI, Mysore has developed a process to obtain starch from seed kernels which can be used to partly replace wheat atta for making chapathis; oil which forms about 12% of the weight of the kernels is another by-product.
4.2	Citrus peels, pomace, etc.	These account for nearly 40% of 1.2 million tonnes of annual citrus fruits in the country.	CFTRI, Mysore has developed an integrated process for economic recovery of oil and pectin from the peels of oranges and lime. These products have good internal and external demand.
4.3	Apple pomace	It is left over after preparation of juice. Its pectin content varies from 2.5-3.4% on fresh weight basis.	CFTRI, Mysore has developed process to prepare pectin, cider and vinegar from pomace.
4.4	Pineapple peels, ears & eyes	These wastes contain 7-8% sugar.	CFTRI, Mysore has standardised a method to prepare syrup out of this juice by using ion exchange resins and also vinegar directly from the processed juice. The residue can be utilised as cattle feed.

4.5	Banana pseudostem	It contains nearly 90% water, 0.5-3.0% starch and 5-8% fibre	CFTRI, Mysore has developed a process to recover starch and fibre from the banana stem. Starch has been found to be useful in food, cosmetics and textile industries and fibre in the manufacture of paper and pulp.
4.6	Wastes from the vegetable canning industries	No significant data are available on these aspects.	

List of Processes Relating to the Utilisation of Agricultural Wastes/By-products

National Committee on Science & Technology, New Delhi

I Regional Research Laboratory, Jorhat

1. Caffeine from tea waste
2. Furfural from agro-industrial wastes
3. Oxalic acid from sawdust and molasses
4. Baker's yeast from molasses
5. Bromelin from pineapple waste
6. Tartaric acid from tamarind leaves
7. Cystin from hair
8. Household detergent, silica flour and bricks from paddy husk
9. Particle board from wood waste without binder
10. Production of moulded products from agro-industrial wastes.

II Regional Research Laboratory, Hyderabad

1. Activated carbon from rice husk
2. Activated carbon from coconut shells
3. Distillation of cashewnut liquid to cardanol and fermentation of different composition products for various end-uses.
4. Chemical cotton from cotton linters
5. Speciality paper from cotton linters and hosiery wastes and agro-wastes.
6. Fatty acids from cotton seed soap stock

III Regional Research Laboratory, Bhubaneswar

1. Hecogenin from sisal waste
2. Oxalic acid from tobacco waste
3. Production of alcohol from mahua flowers
4. Economic products from marine wastes viz. prawns, crabs and trash fish

IV Regional Research Laboratory, Jammu

1. Particle boards from agro-industrial wastes

V National Chemical Laboratory, Poona

1. Tamarind kernel powder (TKPP) phosphate and borate
2. Cashewnut shell gum
3. Gum arabic substitute from tapioca starch
4. Sugarcane wax
5. Nicotine sulphate from tobacco wastes
6. Extraction and utilisation of sisal wax
7. Rubberised cork sheet from waste cork granules
8. Gaskets from coir pith

VI National Botanic Gardens, Lucknow

1. Separation and utilisation of lipid associates from non-edible oilseeds

VII National Sugarcane Research Institute, Kanpur

1. Lactic acid and oxalic acid from sugarcane molasses
2. Extraction and purification of sugarcane wax from press mud

VIII Central Food Technological Research Institute, Mysore

1. Starch from mango seeds and kernels
2. Oil and protein from peels of oranges and lime
3. Pectin, cider and vinegar from apple pomace
4. Syrup and vinegar from pineapple wastes
5. Starch and fibre from banana pseudostem
6. Pectin and tartrate from tamarind fruit pulp
7. Tamarind juice concentrate
8. Papain and pectin from papaya waste
9. Beverages from cashew apple
10. Stabilisation of rice bran and extraction of oil.

IX Central Leather Research Institute, Madras

1. Leather boards from leather waste
2. Utilisation of acid washing, scouring, bleaching and softening of tannery goat hair, wool, buff and camel hair
3. Processing of dry, ready-to-wet sausage casings from cattle, goat, sheep, pig and other mammalian intestines

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4. Manufacture of hide powder
5. Manufacture of tannin extracts using cashew testa
6. Violin bow hair
7. Pig/Hog bristles
8. Tannin extract from tamarind seed husk
9. Surgical sutures from mammlian intestines

X Central Building Research Institute, Roorkee

1. Expansion joint filler from CNSL and coconut
2. Water and weather proofing resin composition based on CNSL
3. Cement coconut pith concrete for thermal insulation
4. Wood wool board
5. Coconut husk particle board

XI Central Fuel Research Institute, Dhanbad

Activated carbon from coconut shell

XII Central Salt and Marine Chemicals Research Institute, Bhavnagar

1. Agar agar from Indian seaweeds
2. Algenic acid and sodium alginate from Indian seaweeds

XIII Central Institute of Fisheries Technology, Cochin

1. Chitosan from prawn wastes
2. Fish meal from fish wastes

XIV Indian Agricultural Research Institute, New Delhi

1. Manure from leather wastes
2. Manure from hair and wool wastes
3. Sterilized bonemeal from cattle bones
4. Bloodmeal from slaughter house blood

XV Indian Lac Research Institute, Namkum

Lac wax from lac effluents

XVI Indian Institute of Petroleum, Dehra Dun

Lanolin from wool grease

XVII Indian Institute of Paper Technology, Saharanpur

1. Pulping of rice straw by neutral sulphite, semi-chemical process for bleachable grade pulp for M/s. Rohit Pulp and Paper Mills Ltd., Gujarat
2. Pulping of wheat straw by neutral sulphite, semi-chemical process for the manufacture of Linear-board-for -M/s. Straw Products, Bhopal
3. Pulping of wheat straw, paddy straw and bagasse by mechano-chemical and bagasse by mechano-chemical and pressure digestion processes for M/s. Dhampur Sugar Mills Ltd., Dhampur

XVIII Jute Technological Research Laboratory, Calcutta

Pulp, paper, viscose rayon and laquor, varnish from jute wastes

XIX Forest Research Institute, Dehra Dun

1. Paper from jute stick
2. Pure catechine from khar trees
3. Distillation oil from the saw–dust of eucalyptus citriodorum

XX Oil Technological Research Institute, Anantpur

Bleaching of crude rice bran oil

XXI Research Design and Standards Organisation, Chittaranjan

1. Epoxy resin cashewnut shell liquid
2. Resin emulsion from cashewnut shell liquid
3. Phosphated products of CNSL/CNSL resin BNSL/BNSL resins

XXII Jadavpur University, Calcutta

Stabilisation of both raw and parboiled bran

XXIII Industrial Testing Research Laboratory, Trivandrum

1. Chemistry of tannins and non–tannins cashew testa
2. Chemistry and uses of cashewnut shell liquid

XXIV Wool Research Association, Bombay

Recovery of wool wax from scour liquor

XXV J. B. Central Research Institute for Village Industries, Wardha

1. Preparation of sterile bonemeal from bones
2. Preparation of dicalcium phosphate from bones
3. Recovery of bone glue in pure grade

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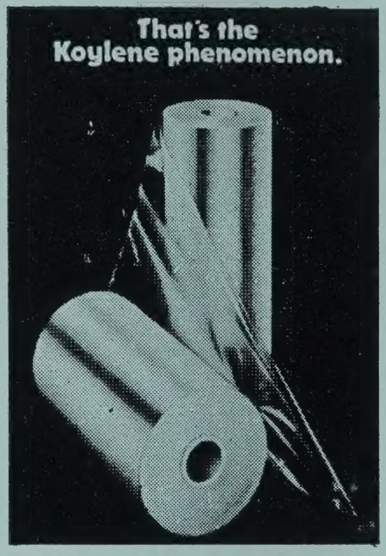

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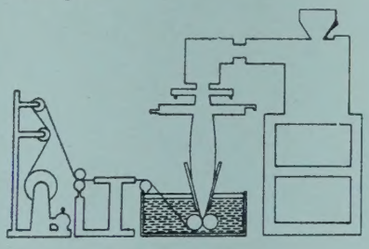

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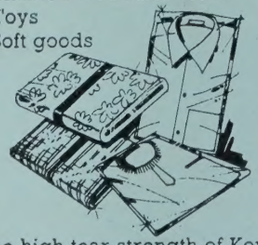
* Toys
* Soft goods



The high tear strength of Koylene TQ films, as compared to cellophane and rigid PVC blown film, gives extra protection to your products in handling. Its intrinsic non-toxicity, coupled with good barrier properties towards water vapour, gases and grease, helps keep food products listed below fresh and hygienic for long.

* Snack foods
* Bakery products like biscuits, breadsticks, bread and cakes
* Candy and toffees.

Koylene films can even be sterilised if required in boiling water or steam for packing surgical and hospital products or nursery seeds.

Switch over to Koylene from IPCL

Koylene is backed by our specialised customer service. A service that offers processors and end-users with technical and promotional assistance for the adaptation of this polymer for existing or new products.

Switch over with confidence. And discover the endless end-uses of Koylene today.

Koylene from IPCL.

The performance polymer.

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